Atmospheric Deposition of Nitrogen compounds in Assam (India)

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Abstract— *The study comprises estimate of wet deposited nitrogenous compounds in Assam (India). Deposition has been estimated from a survey works (2010-11) at urban and peri-urban areas of Assam. Air samples were collected by clinical syringe (10 cm^3) for Oxides of Nitrogen (NO, NO_2: NOx) and reduced Nitrogen (NH_3, NH_4^+: NHy). The samples were diffused into 10 cm^3 each of distilled water and 0.1N HCl respectively for estimation of mean concentration of weighted hydrogen (μeql^{-1}), quantity of elemental nitrogen (N) or nitrate (NO_3^{-1}) and ammonium (NH_4^+) ions expressed in mg l^{-1} or kg $ha^{-1}y^{-1}$. The measured concentrations of the nitrogenous compounds were interpolated with a properly used Kriging Technique on a 1km x 1km grid covering districts characterised by varying congestions of population, vehicular transport and of industrial evidences. There were many fold variations of these air quality parameters among the major sites and locations of the pollutants e.g. nitrogen deposited through aerosol of its oxides ranged from 6.0-38 kg $ha^{-1}yr^{-1}$, whereas nitrogen accumulation from the reduced aerosol was 7-24 kg $ha^{-1}yr^{-1}$. Tissue nitrogen in some indicator plant species (e.g.Pinus longifolia, Ficus benjamina), collected from the square grids of polluted areas was also elevated. Thus, the hypothesis that the North-east India, especially Assam is also facing with enrichment of nitrogenous pollution due to anthropogenic activities, mass vehicular and industrial growth, was tested.*

Keywords— Oxides of nitrogen, reduced nitrogen, weighted hydrogen, aerosols, pollution.

I. INTRODUCTION

The inputs of reactive N (termed here as NH_x:NH_3 and NH_4^+, NO_x :(NO + NO_2), and nitrate (NO_3^-) and nitrite (N_2O) are through increased biological fixation of atmospheric N_2 in certain crops, combustion of fossil fuels and release of NO_x, and production of synthetic fertilizer nitrogen (Galloway *et al*., 1994, 1995). There is an additional release of reactive N from stable soil organic matter as a result of soil disturbance for crop production that is not readily quantifiable (Edu Dorland *et al.*, 2013).

Nitrogen oxides have increased in importance in recent decades as atmospheric pollutants in rapidly growing urban and its surrounding areas of India (Bharali *et al.*, 2012; Vitousek *et. al.*, 1997). Deposition of gaseous Ammonia and particulate NH_4^+ may also contribute to the acidification of the ecosystem (Mohan and Kumar, 1998; McClean *et. al*. 2011). The wet and dry deposited oxides of N redistribute nitrogen throughout the environment. Ammonia as an atmospheric pollutant can contribute to a substantial portion of total deposition of nitrogen (Sutton, Moncrieff and Fowler, 1992). In fact, emissions of ammonia and nitrogen oxides have been strongly increased globally since the 1950s (Galloway *et. al.* 2008). The source of volatilised Ammonia is the intensive agricultural systems related to dairy farming, animal husbandry, whereas nitrogen oxides are linked to mainly anthropogenic activities viz., burning of fossil fuel by traffic, industry and households. So, many natural and semi-natural ecosystems across the world are deposited with the atmospheric nitrogen as a result of short- and long-range transport of the nitrogenous pollutants (Bobbink *et. al.* 2010). Since 1990s, areas recognised historically with high atmospheric N deposition (20–100kgNha^{-1}year^{-1}) have been the central and western Europe, eastern USA, eastern Asia and India. Estimated background inputs (pre-1900s) ranged between 1 and 3 kgNha^{-1} year^{-1} (e.g. Asman *et. al.* 1998; Dentener *et. al.* 2006; Galloway and Cowling 2002). Thus, atmospheric nitrogen deposition and climate variability are both measured as major components of global change (Gaudnik *et al.* 2011). The exploration for possibilities of current deposition of nitrogen in the province of Assam by virtue of any reason needs a strong attention.

II. MATERIALS AND METHODS

*Collection of Air (by clinical syringe,) and vegetation samples during October 2010 to January 2011 for their analyses***:** Air samples were collected for NO_2 concentrations based on diffusion tube measurement (Hyvarinen and Crittenden, 1998) by dissolving 10 cm^3 of it into equal volume of double distilled water, and NH_3 concentrations based on trapping 10 cm^3 air into a 10 ml of 0.1N HCl to analyse NH_4^+ (Harrison *et. al*., 1989). The places for collection of air samples in Northeast India (Latitude 26^o North, Longitude 92^{o}E, Altitude 86.6 meter above the mean sea level) were from Guwahati (district of Kamrup Metro), Jagiroad (Morigaon), Jorhat-Titabor (Jorhat) and Namrup (Dibrugarh). The sites comprised of the highly populated, most traffic congested areas in the cities and towns, factories and industrial complexes (e.g.Pulp and paper industry at Jagiroad, Fertilizer manufacturing complexes at Namrup), Oil refinery at Guwahati). The Kriging Technique (Zapletal, 1998)

was properly used for square grids of size about 1Km x 1Km inside the cities and crop fields nearby National Highways at certain elevation (5-10 feet above ground). The grids consisted of the locations, representative of a range of N deposition loads. We collected some vegetation samples also to examine the possibility of nitrogen deposition in the sampling sites.

The pH values of the aerosols were measured using a digital pH meter**.** Blanks for the oxides of nitrogen with distilled water, and 0.1N HCl for reduced nitrogen were also considered for net deposition of nitrogen. The pH value for blanks for NOx (distilled water only) was 6.61 (with weighted hydrogen ion: -48.2 μll^{-1}), and pH values for blanks for NHy (0.1N HCl only) was 2.7 (with weighted hydrogen ion: 119.39μll^{-1}). The values of the parameters obtained after subtracting the blank values from the solution values were considered as the net values. The values for calculation of weighted hydrogen from pH values in case of NOx (sample dissolved in distilled water) were referred to UKRGAR (1997). The calculation of weighted hydrogen from pH values for NHy (samples dissolved from 0.1N HCl) were done using the equation $\mu eqH^{+}l^{-1}$ = antilog(6-pH) directly. The relationship of pH with respect to weighted hydrogen and nitrogen in samples collected, and the calculations of Nitrate and Ammonium ions or Nitrogen (mgl^{-1}, or kg ha^{-1}), depending upon the quantity of rainfall in the places surveyed are as follows:

Parameters of NO_x: $mgNO_3^{-}l^{-1}$=weighted H^{+} for pH x 0.062**, $gNO_3^{-}ha^{-1}yr^{-1}$ = [**$mgNO_3^{-}l^{-1}$ x amount of rainfall]/1000; **$gNha^{-1}yr^{-1}$** = [$mgNl^{-1}$ x amount of rainfall]/1000, $0.014mgNl^{-1}=0.062mgNO_3l^{-1.}$

Parametrs for NH_y: $mgNH_4^{+}l^{-1}$=weighted H^{+} for pH x 0.018, **$gNH_4^{+}ha^{-1}yr^{-1}$ =** $mgNH_4^{+}l^{-1}$ x amount of rainfall]/1000**; $gNha^{-1}yr^{-1}$ =** [$mgNl^{-1}$ x amount of rainfall]/1000, $0.014mgNl^{-1}=0.018mgNH_4^{+}l^{-1}$. **Wet Nitrogen Deposition:** D_M (gMm^{-2}) = [M](mg l^{-1}) x rainfall (mm) x 10^{-3}

Where D_M is the deposition of ion M and [M] is the concentration, 1g m^{-2} = 10 kg ha^{-1}. In pH scale, lower is the value than the neutral pH (7.0), higher is the value of weighted hydrogen ion, and more is the Nitrogen in the sample.

Annual rainfall data were collected from the respective meteorological observatories situated nearby the air sampling areas. The total annual rainfall data considered for calculations for Guwahati & Morigaon, Jorhat & Titabor, and Namrup & Dibrugarh were 1440.3mm, 2344.10mm and 3129.90mm respectively. Nitrogen contents in the vegetation samples collected from the various polluted and relatively unpolluted sites were also analysed. The Kjeldhal method was used to determine total Nitrogen estimation, which is based on catalytic conversion of organic nitrogen into ammonia and its subsequent estimation by acid base titration (Yoshida, 1976)**.** 500 mg of oven dried (at 60-80^{o}C) samples were digested in a 100 cm^3 Kjeldahl flask. Added the same amount of salt mixture (K_2SO_4 or Na_2SO_4 with $CuSO_4.5H_2O$ and metallic selenium @ 50:10:1 ratio) and 3 ml of concentrated H_2SO_4. Each tube was heated gently and then at increasing intensity up to 400^{o}C after the initial vigorous reaction is subsided. When the digest becomes clear on continued heating for about 1-1.5 hour, allowed 30 minutes to cool it. The digested samples were diluted with 10 ml of distilled water, mixed thoroughly and allowed the sample to cool again. Blank digestions were also carried out.

Automatic analyses of nitrogen were undertaken using the Kjeltech Auto Analyzer. Transferred the digested sample and three rinses with distilled water into the micro-Kjeldahl distillation tube. Then added 10 ml of the 40 per cent NaOH to it. Prepared a 200-ml flask containing 10 ml of 4 per cent boric acid reagent and three drops of mixed indicator (0.3 g of bromo cresol green and 0.2 g methyl red in 400 ml of 90 per cent ethanol). Placed the flask under the condenser of the distillation apparatus, and made sure that the tip of the condenser outlet was beneath the surface of the solution in the flask. Allowed steam from the boiler to pass through the sample, distilling off the ammonia into the flask containing boric acid and mixed indicator solution for about 7 minutes. The tip of the condenser outlet was washed by distilled water. Then, titrated the solution of boric acid and mixed indicator containing the 'distilled off' ammonia with the standardized 0.1 N HCl. The reading was noted down each time and calculations were done as: Total N (%) in sample = [(Sample titre - Blank titre) x normality of HCl x 14 x 100]/ Sample weight (g) x 1000.

III. RESULTS AND DISCUSSION

Results on various parameters of oxidized and reduced nitrogen compounds collected from different sites of urban and peri-urban areas of Assam are presented on **Table (1-4).** There were significant differences of weighted hydrogen, nitrate, ammonia and elemental nitrogen present in the aerosols of oxidized and reduced nitrogen. The four major sites and also the specific locations of sample collections varied significantly. The concentrations of weighted hydrogen, nitrate, ammonium ions and content of elemental nitrogen increased in the aerosol samples collected near the sources of NOx & NHy emissions as compared to the samples taken away from the relatively unpolluted areas. The annual average total wet depositions of nitrogen compounds estimated in the province of Assam were NO_3^{-}:23.83, 72.63, 112.33, 104.79 $kgha^{-1}yr^{-1}$ and NH_4^{+}: 10.65, 35.78, 26.42, 97.06 $kgha^{-1}yr^{-1}$ for the districts of Kamrup, Morigaon, Jorhat and Dibrugarh respectively (Table 1-4).

TABLE 1

PARAMETERS ON AEROSOL PRODUCTS OF NO_X AND NH_y SAMPLES FROM EACH THREE MAJOR SITES (I, II & III) AT GUWAHATI CITY (KAMRUP DISTRICT OF ASSAM)

Parameters **(Mean values)**	**Mean of ten NO_x samples (S) from each site**										
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**Blank (Without air sample)**
PH of Air sample in distilled water	5.1	**5.3****	4.9	**4.8***	4.97	5.1	5.0	5.0	5.1	4.9	6.61 (distilled water only)
Weighjted H^+ (μeql^{-1})	120	**70***	140	**207****	173	93	103	113	93	130	< 0
mg $NO_3^- l^{-1}$	7.44	**4.34**	8.7	**12.8**	10.75	5.79	6.41	7.03	5.79	8.06	0
kg $NO_3^- ha^{-1} yr^{-1}$	17.59	**10.94**	**38.16**	32.55	19.07	20.92	29.85	22.49	20.92	26.52	0
kg N $ha^{-1} yr^{-1}$	24.19	**14.11**	28.23	**41.7**	34.95	18.82	20.83	22.85	18.8	26.21	0
Mean of ten NHy samples from each site											
PH of Air sample in 0.1N HCl	**1.12****	0.947	1.03	1.07	1.06	10.9	**0.89**	1.01	0.98	0.987	2.7 (0.1N HCl only)
Weighjted H^+(μeql^{-1})	**158.4***	162	160.2	159.5	159.6	159	**163**	160.6	161.	161.1	119.39
mg $NH_4^+ l^{-1}$	**2.85**	**2.92**	2.887	2.870	2.873	2.863	2.933	2.890	2.90	2.90	2.975
kg $NH_4^+ ha^{-1} yr^{-1}$	**41.07**	42.0	41.54	41.36	41.38	41.22	**42.26**	41.65	41.8	41.76	30.95
kg N $ha^{-1} yr^{-1}$	**37.94**	38.86	38.38	38.21	38.18	38.03	**39.06**	38.45	38.6	38.55	24.07

Site-I: Around Oil Refinery at Guwahati (S1:Noonmati refinery, (S2:Noonmati training centre, S3:Noonmati main gate, S4:Noonmati sector 3, S5:Birkuchi, S6:Patherkuwari,S7:Narengi oughuli road, S8:Narengi Junior college, S9:Narengi Tiniali, S10:New Guwahati Baminimaidan

Site-II: Around Maligaon: (S1-S5):Adabari Buses' stand-(S6-S7):Near Assam Engineering College, (S8-S9):near Sarighat Bridge at Jalukbari, S10: Towards Gopinath Bordoloi Airport

Site-III: (S1-S2):Manik Nagar, (S3-S5):Rajdhani Nursery, (S6-S8):Baisistha, (S9):Near Reginal passport office, (S10)Near Arohan , Beltola

*** The lowest pH value (highest acidity) with maximum H^+ concentration**

****Highest pH value (lowest acidity) with minimum H^+ concentration**

TABLE 2
PARAMETERS ON AEROSOL PRODUCTS OF NO_x AND NH_y AT JAGIROAD (MORIGAON DISTRICT OF ASSAM)

Parameters	Mean of sixteen NO_x samples (S) at Jagiroad																
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**Blank**
PH of Air sample in distilled water	5.4	5.3	5.3	5.4	**5.5****	5.2	5.3	5.3	5.2	**4.9***	5.2	5.4	5.4	5.5*	5.4	5.1	6.61 (distilled water only)
Weighjted $H^+(\mu eql^{-1})$	45	50	55	35	30*	60	50	50	50	100**	55	40	40	30	40	80	< 0
mg $NO_3^-l^{-1}$	2.79	3.10	3.41	2.17	1.86	3.72	3.10	3.10	3.10	6.20	3.41	2.48	2.48	1.86	2.48.	4.96	0
kg NO_3^- $ha^{-1}yr^{-1}$	40.18	44.65	49.11	31.25	26.79	53.58	44.65	44.65	44.65	89.30	49.11	35.72	35.72	26.79	35.72	71.44	0
kg N $ha^{-1}yr^{-1}$	9..07	10.08	1109	7.06	6.05	12.10	10.08	10.08	10.08	20.16	11.09	8.07	8.07	6.05	8.07	16.13	0
Mean of sixteen NHy samples at Jagiroad																	
PH of Air sample in 0.1N HCl	0.857	**0.59***	0.857	1.07	0.97	1.07	0.97	0.97	0.88	1.14	0.97	0.93	0.95	0.78	1.18	**1.75****	2.7 (0.1N HCl only)
Weighjted $H^+(\mu eql^{-1})$	163.6	**168.5****	163.8	159.4	161.5	159.5	161.5	161.5	163.2	158.1	161.5	162.4	162	165.3	157.3	**144.7***	119.39
mg NH_4^+ l^{-1}	2.947	3.033	2.95	2.870	2.091	2.873	2.910	2.910	2.940	2.850	2.907	2.923	2.917	2.970	2.830	2.60	2.975
kg NH_4^+ $ha^{-1}yr^{-1}$	42.42	43.68	42.46	41.34	41.88	41.35	41.88	41.88	42.32	40.99	41.87	42.10	42.00	42.84	40.77	37.51	30.95
kg N $ha^{-1}yr^{-1}$	32.99	33.97	29.36	32.15	32.57	32.16	32.57	32.57	32.91	31.88	32.57	32.74	32.66	33.32	**31.71**	25.85	24.07

In Table 2 Morigaon District: Nawgaon Paper Mill and nearby areas:

(S1) Near ASTC, (S2) Near industry, (S3) CISF Unit, (S4) Choudhury Nursery, (S5) Near Main Gate (1), (S6) Wall (Main Gate), (S7) Residential area (A), (S8) Near Main Gate (2), (S9) Near field, (S10), Kendriya Vidyalay, (S11) Near ATM, (S12) Residential area (B), (S13) Near Factory, (S14) Near Servo petrol pump, (15) near Trucks' stand, (16) Near Field. *** The lowest pH value (highest acidity) with maximum H^+ concentration, **Highest pH value (lowest acidity) with minimum H^+ concentration**

TABLE 3
PARAMETERS ON AEROSOL PRODUCTS OF NO_x AND NH_y AT TWO SITES OF JORHAT DISTRICT (SITE 1:TITABOR &SITE2:JORHAT) OF ASSAM

Parameters	Mean of ten NOx samples (S) each at Jorhat and Titabor										
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**Blank (Without air sample)**
PH of Air sample in distilled water	5.317	5.26	**5.66****	5.54	5.46	5.01	5.08	5.42	4.99	**4.67***	6.61 (distilled water only)
Weighjted $H^+(\mu eql^{-1})$	39.33	66.67	**26.67***	33.33	43.33	50.00	58.33	66.67	130.0	**193.33****	< 0
mg $NO_3^-l^{-1}$	3.93	4.13	1.65	2.07	2.69	3.10	3.62	3.24	8.54	11.99	0
kg $NO_3^-ha^{-1}yr^{-1}$	92.04	96.89	98.75	48.45	62.98	72.67	84.78	96.89	188.9	280.99	0
kg N $ha^{-1}yr^{-1}$	20.783	21.877	8.75	17.14	19.65	23.22	26.29	29.34	35.13	55.92	0
Mean of ten NHy samples each at Jorhat and Titabor											
PH of Air sample in 0.1N HCl	**1.26***	1.38	1.39	1.43	1.44	1.45	1.55	1.60	**1.68****	1.49	2.7 (0.1N HCl only)
Weighjted $H^+(\mu eql^{-1})$	**155.6****	152.9	152.7	151.9	151.4	151.3	149.3	148.1	**146.2***	150.5	119.39
mg $NH_4^+ l^{-1}$	2.797	2.750	2.750.	2.733	2.723	2.723	2.687	2.670	2.633	2.713	2.975
kg $NH_4^+ha^{-1}yr^{-1}$	66.65	64.51	64.44	64.11	63.91	63.84	62.98	62.50	61.70	63.52	30.95
kg N $ha^{-1}yr^{-1}$	51.06	50.18	50.12	49.86	49.70	49.65	48.98	48.61	47.99	49.41	24.07

SiteI: Rice growing areas towards Titabor**:** (S1) Namghar area , Titabor, (S2):Regional Rice research station Titabor, (S3): Titabor tiniali,, (S4):Titalbaor Chariali, (S5):Chinamora tiniali, (S6): Gatany factory, (S8-S10): ONGC area, Cinnamora;

Site II: Jorhat town: (S1):Samples from Cinnamora railgate, :Cinamora petrol pupm, (S2): Lahoti petrol pump, (S3):AT Road, Joraht town, (S4): Bhogdoi bridge, & AT Road, Borpool, (S5):samples from Garali, Dos & Co. (S6): Borbheta Tiniali,, Rowraia chariali, Civil Hospital, Jorhat, (S7):Baruah chariali, ASTC, Jorhat, (S8): Malowali Tiniali, (S9):Tarajan, Byepass, (S10): Dikha Nursery & Moubandha,

*** The lowest pH value (highest acidity) with maximum H^+ concentration, **Highest pH value (lowest acidity) with minimum H^+ concentration**

TABLE 4
PARAMETERS ON AEROSOL PRODUCTS OF NO_X AND NH_y AT NAMRUP (DIBRUGARH DISTRICT OF ASSAM)

NOx samples (S) around Barak Valley fertilizer Corporation of India Ltd. Namrup																
Parameters	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**Blank (Without air sample)**
PH of Air sample in distilled water	5.45	**5.55****	5.35	5.45	**5.35***	5.50	5.45	5.50	5.50	5.45	5.50	5.45	5.50	5.45	5.40	6.61 (distilled water only)
Weighjted H^+ (μeql^{-1})	40.0	**35.0***	55.0	40.0	**45.0***	35.0	40.0	35.0	35.0	35.0	35.0	35.0	35.0	40.0	40.0	< 0
mg $NO_3^-l^{-1}$	2.480	2.170	3.410	2.480	2.790	2.170	2.480	2.170	2.170	2.170	2.170	2.170	2.170	2.480	2.480	0
kg $NO_3^-ha^{-1}yr^-$	77.62	67.92	106.73	77.62	87.32	67.92	77.62	67.92	67.92	67.92	67.92	67.92	67.92	77.62	77.62	0
kg N $ha^{-1}yr^{-1}$	17.53	15.34	24.10	17.53	19.72	15.34	17.53	15.34	15.34	15.34	15.34	15.34	15.34	17.53	17.53	0
NHy samples around Barak Valley fertilizer Corporation of India Ltd. Namrup																
PH of Air sample in 0.1NHCl	1.135	1.23	1.395	1.24	1.44	1.14	**1.49****	1.14	1.17	1.09	**1.08***	1.29	1.20	1.16	1.25	2.7 (0.1N HCl only)
Weighjted $H^+(\mu eql^{-1})$	158.2	156.2	152.7	156.1	151.6	158.2	**150.4***	158.2	157.4	159.2	**159.3****	155.5	156.8	157.7	155.9	119.39
mg $NH_4^+ l^{-1}$	2.85	2.81	2.75	2.81	2.73	2.8/5	2.71	2.82	2.81	2.87	2.87	2.79	2.85	2.84	2.81	2.975
kg $NH_4^+ha^-$ $^1yr^{-1}$	89.12	87.99	86.14	87.96	45.42	89.12	84.76	89.12	88.71	89.69	89.76	87.31	88.36	88.83	87.81	30.95
kg N/$ha^{-1}yr^{-1}$	69.32	68.43	66.92	68.41	66.43	69.32	65.92	69.32	68.99	69.76	69.81	67.90	68.72	69.10	68.29	24.07

Namrup : Around Brahmaputra Valley Fertilizer corporation (BVFC) Pvt. Ltd., Duliajan and Dibrugarh: **(**S1): BVFC Gate, (S2):inside BVFC, (S3): Loha Gate 10km away from BVSC, (S4) Oil collecting site, Jaipur (S5):Naharkotia Market, (S6-S7)Tipling Duliajan, (S8):Chaukidinghi, (S9):Dibrugarh, (S10):Dibrugarh Chalkhowa station, (S11):): Duliajan Oil market, (S12): Duliajan Uco Bank, (S13):Duliajan Chariali, (S14):Near Oil India, (S15):Near Police Station

Conversions as per UKRGAR (1997):Weighted H^+ (μeql^{-1}) for NO_x and NH_y =ln (6-pH), Parametrs for NO_x**: $mgNO_3^-l^{-1}$=**weighted H^+x 0.062**, $gNO_3^-ha^{-1}yr^{-1}$ = [**$mgNO_3^-l^{-1}$ x amount of rainfall]/1000; $gNha^{-1}yr^{-1}$ = [$mgNl^{-1}$ x amount of rainfall]/1000

Parametrs for NH_y: $mgNH_4^+l^{-1}$=weighted $H^+(\mu eql^{-1})$ x 0.018, $gNH_4^+ha^{-1}yr^{-1}$ = $mgNH_4^+l^{-1}$ x amount of rainfall]/1000**; $gNha^{-1}yr^{-1}$ =** [$mgNl^{-1}$ x amount of rainfall]/1000

*** The lowest pH value (highest acidity) with maximum H^+ concentration**

****Highest pH value (lowest acidity) with minimum H^+ concentration**

TABLE 5
GUWAHATI AND ITS PERIURBAN AREAS (KAMRUP DISTRICT)

S. No.	Samples (Local with Botanical names)	Nitrogen %
1	Forget me not (*Hydrangea macrophyla*)	2.579
2	Kanchan (*Bouhinia alba*)	2.492
3	Hasnahana (*Cestrum nocturnam*)	2.268
4	Ficus (*Ficus benzamina)*	1.344**
5	Litchi (*Litchi chinensis*)	0.924
6	Titasopa (*Michelia champaca*)	2.94
7	Gerbera (Gerberas anandria)	1.176
8	Arjun (*Terminalia arjuna*)	1.54
9	Radhasura (*Delonix regia)*	1.904
10	Bottlebrass (*Callistemon lanceolatus*)	1.148
11	Gamari (*Gmelina arborea*)	1.568
12	Aralia (*Aralia apioides*)	2.716
13	Boga chandan (*Santalum album* L)	0.728
14	Pine (*Pinus longifolia)*	1.344**
15	Thuja (*Tthuja orientalis)*	0.70

TABLE 6
ADJOINING AREAS OF NAGAON PAPER MILL, JAGIROAD (NAGAON DISTRICT)

S. No.	Samples	Nitrogen %
1	*Dahlia* (*Dahlia coccinea*)	0.784
2	Zerenium (*Pelargonium hortorum*)	1.184
3	Silverdust (*Centaurea cineraria*)	0.504
4	Dianthus *(Dianthus chinensis)*	0.28
5	Pancy (*Viola tricolour*)	0.224
6	*Gerbera (Gerbera jamesonii*)	0.168
7	Ficus (*Ficus benjamina*)	0.364*
8	Ashok (*Saraca indica*)	0.196
9	*Ixora* (*Ixora coccinea*)	0.308
10	Tomato (*Solanum lycopersicum)*	0.112
11	Brinjal (*Solanum melogana*)	0.224
12	*Cabbage* (*Brassica oleraceae*)	0.14
13	Mausombi (*Citrus raticulata*)	0.336

In Table 5-8: Lowest value (*), Highest value (**) of the same species at different locations.

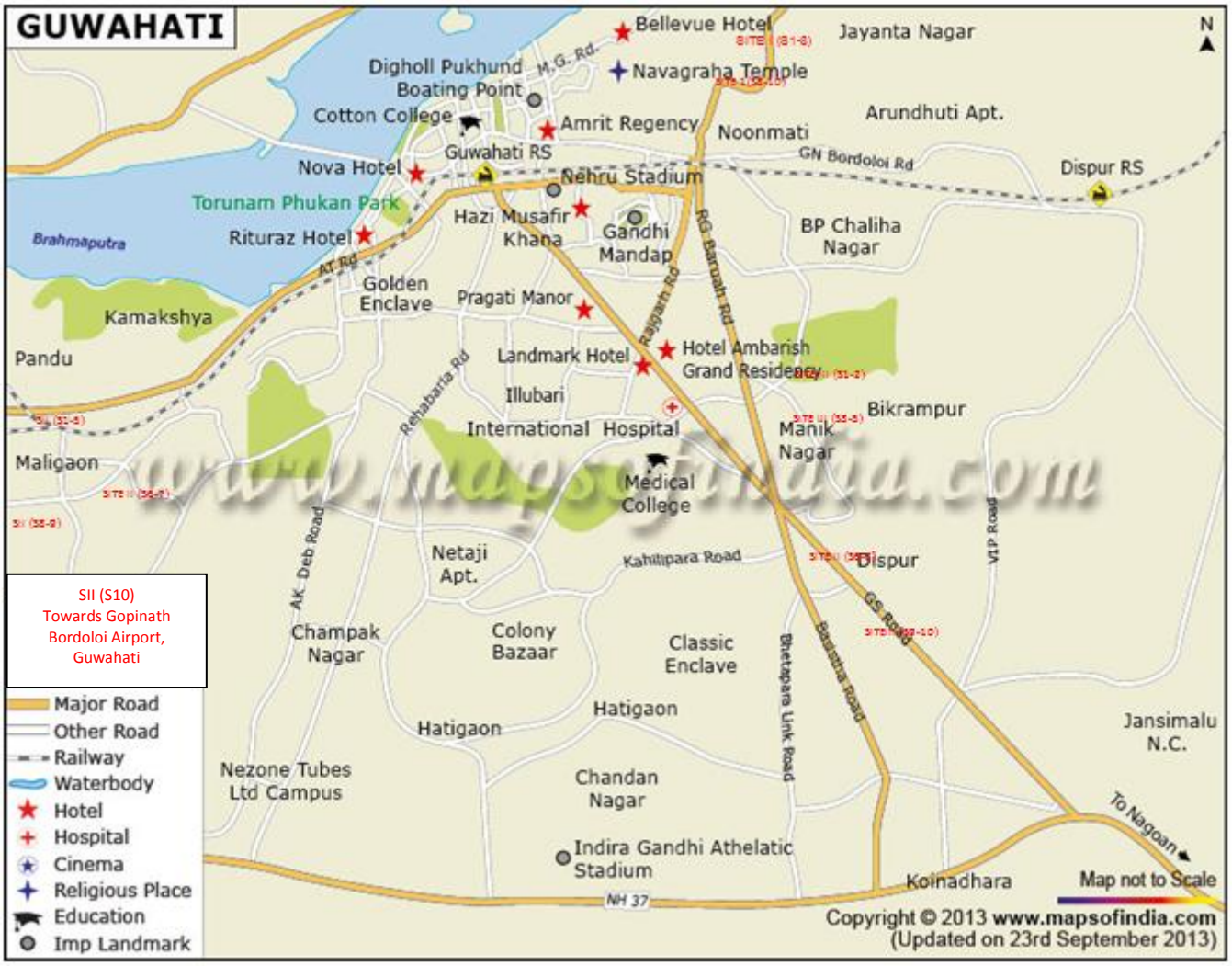
TABLE 7
JORHAT DISTRICT OF ASSAM (JORHAT & TITABOR)

S. No.	Samples	Nitrogen %
1	Rice (*Oryza sativa L.*)	0.056
2	Marygold (*Tagetis erecta*)	0.056
3	Bakul *(mimusops elengi)*	0.084
4	Hedge plant (*Ccleodendron inerme*)	0.168
5	Hibiscus (*Rosa sicencis*)	0.196
6	*Khutara (Amaranthus viridi)*	0.224
7	Thuja (*Thuja orientalis*)	0.112
8	Pine (*Pinus longifolia)*	0.140*
9	Mussanda (*Musanda philippica*)	0.168
10	Bougainvillea (*Bougainvillea spp*.)	0.364
11	Mango (*Mangiffera indica* L.)	0.168
12	Rabab Tenga (*Citrus grandis*)	0.196
13	Clove (*Syzygium aromaticum*)	0.224
14	Guava (*Psidium guajava*)	0.140
15	Peeple (Ficus religosa)	0.150
16	Tomato (*Solanum lycopersicum*)	0.168
17	Pumkin (*Cucurbita moschata)*	0.140
18	Rice (*Oryza sativa* L)	0.168

TABLE 8
BRAHAMAPUTRA FERTILIZER CORPORATION PVT. LIMITED, NAMRUP (DIBRUGARH DISTRICT)

S. No.	Samples	Nitrogen %
1	Bamboo (*Bambusa textiles*)	*0.168*
2	Carpet grass (*Axonopus fissifolius)*	*0 .196*
3	People tree (*Ficus relegiosa)*	*0.084*
4	Krishnasura (*Delonix regia)*	0.112
5	Creeper fruit (*Quisqualis indica)*	0.014
6	Papaya (*Carica papaya*)	0.112
7	Gourd (*Lagenaria siceraria)*	0.56
8	Knolkhol (*Brassica oleraceae)*	0.84
9	Potato (*Solanum tuberosum)*	0.112
10	Lai sak (*Brassica juncea)*	0.168
11	Black pepper (*Piper nigram)*	0.112
12	Tea (*Camalia sinensis*)	0.14
13	Brinjal (*Solanum melogana)*	0.196

The analyses of vegetation samples from the polluted sites (e.g. city of Guwahati) also revealed the enrichment of tissue nitrogen while compared to the nitrogen content in the same plant species from the distant relatively unpolluted places (**Table 5-8**). N is the primary limiting nutrient for plant growth in many natural and semi-natural ecosystems, especially under oligotrophic and mesotrophic conditions in temperate and boreal regions (Bobbink *et. al.* 2010; Sala *et. al.* 2000). Many plant species in such ecosystems are adapted to nutrient-poor conditions, and can only survive or compete successfully on soils with low N availability (Aerts and Chapin 2000; Tamm 1991). The series of events which occur when N inputs increase in an area with originally low background deposition rates is complex. Many ecological processes interact and operate at different temporal and spatial scales. As a consequence, large variations in sensitivity to atmospheric N deposition have been observed between different natural and semi-natural ecosystems (e.g. Maskell *et. al.* 2010). The increased N deposition may impact on foliar toxicity, changes in structure and function of plant species by soil-mediated effects of acidification, such as stunted root growth by NHy. All these may largely linked to significant changes in the N cycle, in vegetation composition and in plant diversity in many ecosystems of high nature conservation value (Bobbink *et. al.* 2010, 1998).

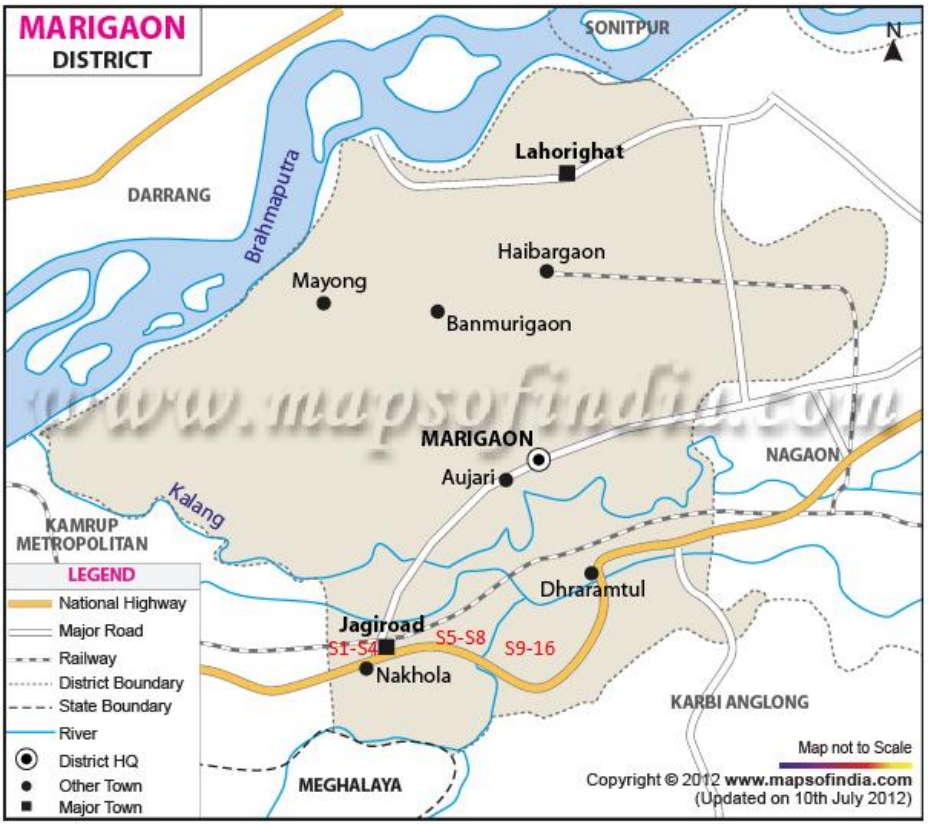


SITE MAP1: GUWAHATI CITY AND SURROUNDING AREAS

Site-I: Around Oil Refinery at Guwahati (S1:Noonmati refinery, (S2:Noonmati training centre, S3:Noonmati main gate, S4:Noonmati sector 3, S5:Birkuchi, S6:Patherkuwari,S7:Narengi oughuli road, S8:Narengi Junior college, S9:Narengi Tiniali, S10:New Guwahati Baminimaidan

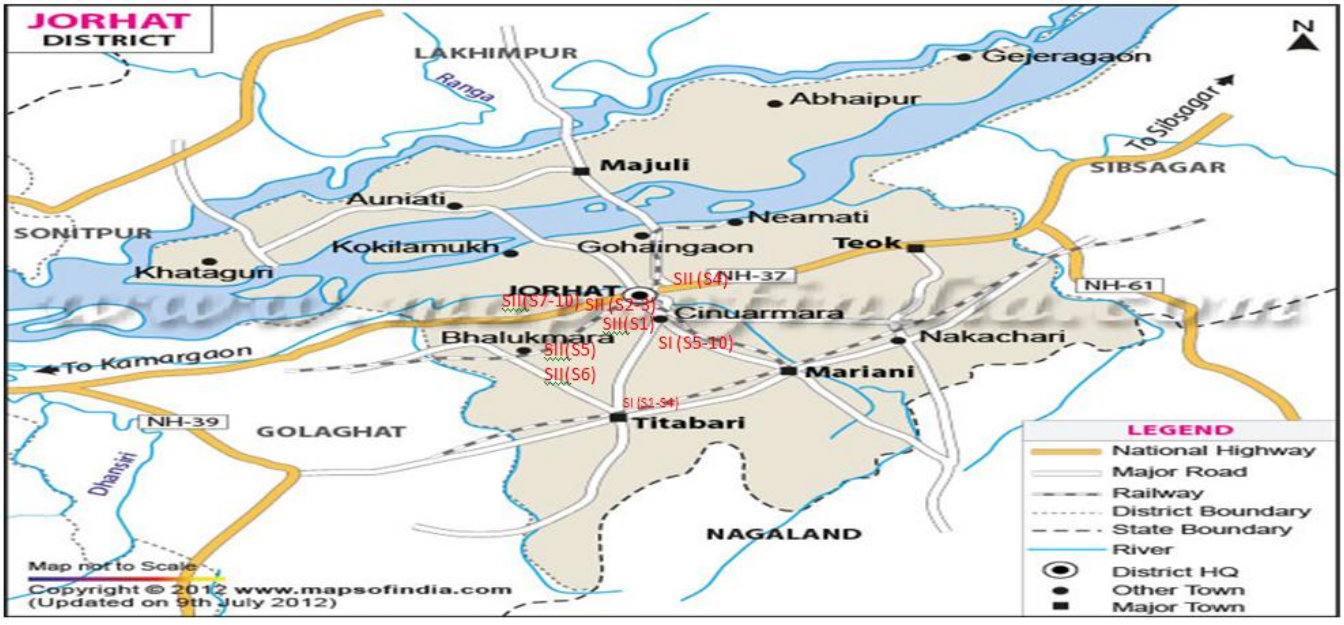
Site-II: Around Maligaon: (S1-S5):Adabari Buses' stand-(S6-S7):Near Assam Engineering College, (S8-S9):near Sarighat Bridge at Jalukbari, S10: Towards Gopinath Bordoloi Airport

Site-III: (S1-S2):Manik Nagar, (S3-S5):Rajdhani Nursery, (S6-S8):Baisistha, (S9):Near Reginal passport office, (S10)Near Arohan , Beltola



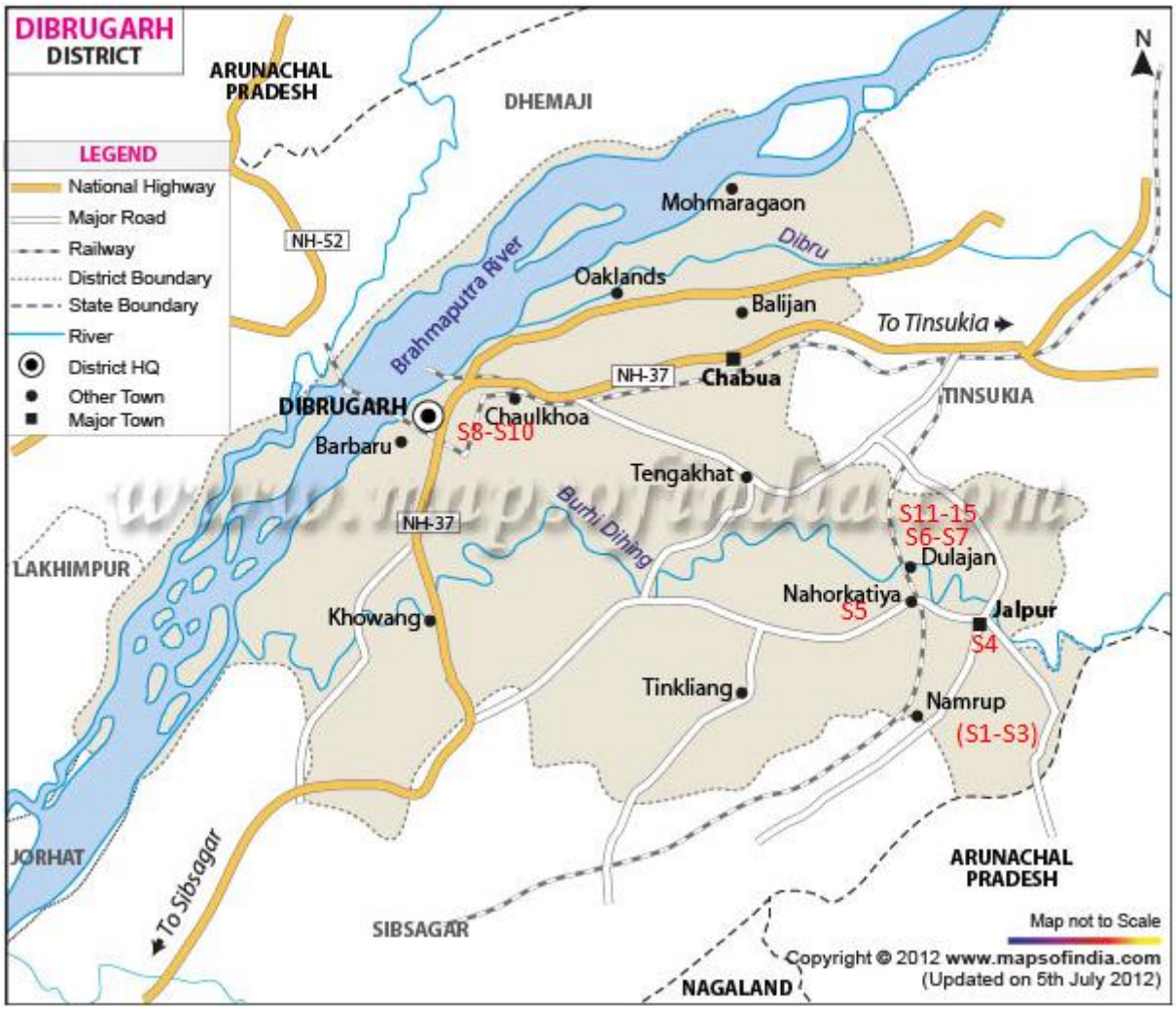
SITE MAP2: MORIGAON DISTRICT: NAWGAON PAPER MILL AND NEARBY AREAS

(S1) Near ASTC, (S2) Near industry, (S3) CISF Unit, (S4) Choudhury Nursery, (S5) Near Main Gate (1), (S6) Wall (Main Gate), (S7) Residential area (A), (S8) Near Main Gate (2), (S9) Near field, (S10), Kendriya Vidyalay, (S11) Near ATM, (S12) Residential area (B), (S13) Near Factory, (S14) Near Servo petrol pump, (15) near Trucks' stand, (16) Near Field.



SITE MAP3: JORHAT DISTRICT OF ASSAM

SiteI: Rice growing areas towards Titabor**:** (S1) Namghar area , Titabor, (S2):Regional Rice research station Titabor, (S3): Titabor tiniali,, (S4):Titalbaor Chariali, (S5):Chinamora tiniali, (S6): Gatany factory, (S8-S10): ONGC area, Cinnamora;
Site II: Jorhat town: (S1):Samples from Cinnamora railgate, :Cinamora petrol pupm, (S2): Lahoti petrol pump, (S3):AT Road, Joraht town, (S4): Bhogdoi bridge, & AT Road, Borpool, (S5):samples from Garali, Dos & Co. (S6): Borbheta Tiniali,, Rowraia chariali, Civil Hospital, Jorhat, (S7):Baruah chariali, ASTC, Jorhat, (S8): Malowali Tiniali, (S9):Tarajan, Byepass, (S10): Dikha Nursery & Moubandha,



SITE MAP4: NAMRUP: AROUND BRAHMAPUTRA VALLEY FERTILIZER CORPORATION (BVFC) PVT. LTD., DULIAJAN AND DIBRUGARH:

(S1): BVFC Gate, (S2):inside BVFC, (S3): Loha Gate 10km away from BVSC, (S4) Oil collecting site, Jaipur (S5):Naharkotia Market, (S6-S7)Tipling Duliajan, (S8):Chaukidinghi, (S9):Dibrugarh, (S10):Dibrugarh Chalkhowa station, (S11):): Duliajan Oil market, (S12): Duliajan Uco Bank, (S13):Duliajan Chariali, (S14):Near Oil India, (S15):Near Police Station

Air samples were collected from major urban and peri-urban areas of Assam (Refer to Site Maps: 1-4). On an average, about 40 kg Nitrogen was deposited from each of oxidised and reduced forms. The vegetation samples collected from the square grids nearing the highways and locations away from the emission sources provide evidences that air is concentrated with the nitrogenous pollutants. There is higher Nitrogen content in the tissues of plants surrounding the cities than in the same or other plants abundant away from the emitters**.** Port and Thomson (1980) also reported that landscape plants closer to highways frequently grow in poor soil conditions, and have elevated levels of total nitrogen in their tissues. The changes have been brought about by emissions from mass vehicles or industrial sources. In Assam, there are increases in number of vehicles, especially in the greater Guwahati City (Kamrup district), and growth of different smaller industries in larger scale in its adjoining areas. Air enriched with Ammonia is evident around the pulp-paper industry at Jagiroad (Nagaon district), and fertilizer manufacturing factory at Namrup (Dibrugarh district). The smaller urban areas (e.g. Jorhat District) were also not getting rid of these pollutants with the presence of considerable number of vehicles, probably some of them are old and their efficiency is lower. Deposition of N-aerosols was much more dispersed than reduced ammonia aerosols generally due to the vehicular growth. The larger agricultural areas accompany the later and intensive live stocks raring units also. Sheppard *et. al*. **(**1988) pointed that incorporation of CNG in vehicles might be another cause of increasing ammonia near highways at distance up to 500 meters. Pitcairn *et. al*. (2002) reported that annual mean concentration of NH_3 close to live stock building were very large (60µgm^{-3}), and declined to 3 µgm^{-3} at a distance of 650 m from the building. The estimated total N deposition ranged from 80kg N ha^{-1} year^{-1} at a distance of 30 m to 14kgNha^{-1}year^{-1} at 650 m downward. In our studies also

the mean deposition of nitrogen by NOx was 6-38kgha^{-1}yr^{-1}, whereas by NHy was 7-24kgha^{-1}yr^{-1} from all the sites. The annual average of total deposition of nitrogen compounds in state has been computed as the sum of the annual averages of wet deposited nitrogen in the representative districts of Assam. Thus, a total maximum deposition of N through oxidized and reduced forms of Nitrogen together is about 18-46 kg ha^{-1}yr^{-1}. Spatial distribution of total respective depositions of NOx and NHy on a 1km x 1 km grid in 2010-11 is shown as sites (urban and peri-urban areas) of sample collections in the district maps for better orientation. Several significantly different gradients for NOx and NHy were recognized for the sites as well as the locations of sample collections. Plausibly, the total deposition of the former was especially influenced by their emissions from populated cities and larger vehicular traffic congested areas. The reasons for the later were mostly influenced by depositions from industries (e.g. pulp & paper factory at Jagiroad, fertilizer factory at Namrup), and intensive cultivable as well as animal rearing hot spots of the urban and peri-urban areas in the state.

IV. CONCLUSION

The wet deposited nitrogen (NOx, NHy and their compounds) was estimated following a square grid (1km x1km) resolution in a few major districts of Assam. The deposition had been assessed from the measured and modeled concentrations of acidifying compounds in the atmosphere and the precipitations with reference to UKRGR (1997).Net deposition of Nitrogen through its oxides ranged from 6.0-38kgha^{-1}yr^{-1}, whereas net deposition of nitrogen by ammonia was in between 7-24 kgha^{-1}yr^{-1}. A total maximum deposition of N through oxidized and reduced forms of Nitrogen together is about 18-46 kg ha^{-1}yr^{-1}. The hypothesis that Assam (especially Guwahati and its adjoining areas) is also facing with enrichment of nitrogenous pollution due to anthropogenic activities and mass vehicular and industrial growth was tested positive.

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