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SIMULATION OF NITROGEN LOSSES FROM FLOODED RICE FIELDS USING WIND TUNNEL EXPERIMENT

by
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ABSTRACT

A research has been done to study the effect of wind on fertilizer losses from rice paddies. The main aim of the study was to identify the major parameters influencing the process of ammonia (NH_3) volatilization from the water surface in a microplot. The study was conducted employing a construction of a 15.6 metre long test section of a wind tunnel with 1.0 metre square cross section. Ammonia concentration experiments were carried out to determine the amount of ammonia that evaporated into the atmosphere. The tests were performed in Civil Engineering laboratory of Institut Teknologi MARA, Shah Alam, using the wind tunnel with 0.25 metre deep and 1 metre wide water channel as a prototype rice-paddy-field condition.

Water samples were taken and analysed using indophenol blue colour method. The results of the study showed that factors such as pH of water samples, wind speed and ammoniacal-N concentration of floodwater influence the NH_3 volatilization. The experiments indicated that ammoniacal nitrogen concentration directly influences the flood water NH_3 (aq), whereas the effects of pH and temperature result in fractional dissociation of ammoniacal-N.

Keywords: Hydrolysis, ammonia volatilization, wind tunnel, ammoniacal-N concentration, floodwater, wind speeds and the pH value.

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BACKGROUND

Ammonia volatilization is the transfer of ammonia (NH_3) from floodwater to the atmosphere across a water-air interface. A number of workers has established that the major mechanisms for Nitrogen (N) loss following the application of fertilizer in floodwater are losses due to ammonia (NH_3) volatilization and nitrification-denitrification. The losses of ammoniacal-N fertilizer applied directly to flood water may vary from 10 to 50 percent of amount applied (Fillery and Vlek, 1986). The result from MARDI studies shows that the highest ammonia flux density occurred on the second day after urea application. The maximum rate of ammonia loss was found to be 0.35 kg/ha/hr (Aziz, *et. al.*, 1990)

INTRODUCTION

When farmers use urea to fertilize their rice paddies, large fertilizer losses may result when, after hydrolysis of the urea, ammonia is produced in the floodwater. Ammonia is volatile and can escape into the atmosphere. The wind, pH and alkalinity of the floodwater determine to a large extent the amount of ammonia that will evaporate into the atmosphere. In this wind-tunnel study the effect of wind on ammonia volatilization was studied.

The hydrolysis of the NH_3 volatilization from flood water can be written as

$$NH_4^+ \underset{k_a}{\overset{k_d}{\rightleftharpoons}} H^+ + NH_3\,(aq) \xrightarrow[\text{}]{\text{volatilization } k_{vn}} NH_3\,(gas)$$

where,

K_d = dissociation rate constant for NH_4/NH_3 equilibrium, first order
K_a = dissociation rate constant for NH_4/NH_3 equilibrium, (second order)
K_{vn} = volatilization rate constant for NH_3, first order,

The rate of change of ammoniacal-N (NH_3-N and NH_4-N) concentration (AN) in the flood water is equal to the rate at which the ammoniacal-N (or C) escapes from the water surface. Therefore

$$\frac{dAN}{dt} = -kC \quad \text{.......................................} \quad (1)$$

It has been found that

$$[AN] = [AN]_o \exp(-k\,t_p) \quad \text{..............................} \quad (2)$$

where $[AN]_o$ is the initial ammoniacal-N concentration, k is NH_3 volatilization constant rate and t_p is the time that corresponds to the situation in which pH and temperature (T) would have remained the same to the initial values throughout the experimental run.

WIND TUNNEL FACILITIES

A schematic of the wind tunnel is shown in Figure 1. This tunnel with its accessories, provides a complete facility for the study of ammonia volatilization.

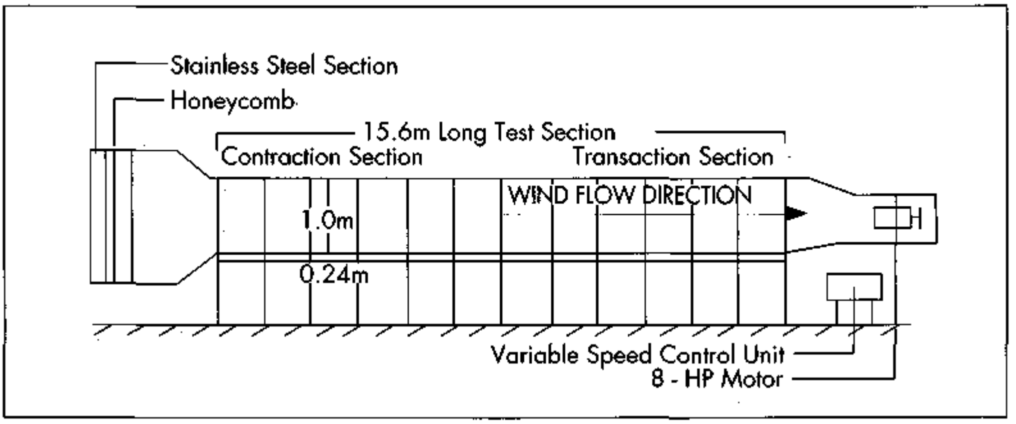

Fig. 1 Schematic of Wind Tunnel

The tunnel consists of a settling chamber, contraction, test section, diffuser and fan section. The cross-section of the test section is 1m x 1m, not including the 0.25m deep and 1m wide water channel. The test section is 18m long assuring a thick turbulent boundary layer and a wind-agitated wave field at the downwind end of the test section.

It has clear acrylic panels along one side and at the bottom of the entire test section for easy flow visualization. Water samples were taken and analysed using indophenol blue colour method.

METHOD

The condition of the ammonia volatilization was carried out for the section between the vertical plate with 3 and 5cm rim heights. The effect of wind at various speeds on the ammonia volatilization rates were measured from the channel without the change in water depth and rim height of the microplot. Ammonia carbonate solution was prepared by dissolving 82.268g of ammonia carbonate [$(NH_4)2\ CO_3$] with 500ml of tap water.

To obtain ammonia concentration measurements the wind tunnel is thoroughly cleaned with the base of the tunnel being scrubbed and rinsed to remove all loose particles. The tunnel was then filled with tap water to a depth of exactly 0.24m and kept still for 24 hours for stability.

Initial pH value was taken before the addition of ammonia carbonate. The wind tunnel was run to the desired speed for one hour until the water temperature in the channel was stable. The water temperature was measured and tabulated. After one hour the fan was shut off and equal amounts of ammonium carbonate solution were introduced into channel starting from down wind end of the test section. The wind tunnel was rerun and then water samples were taken from the microplot at point X (see Figure 2).

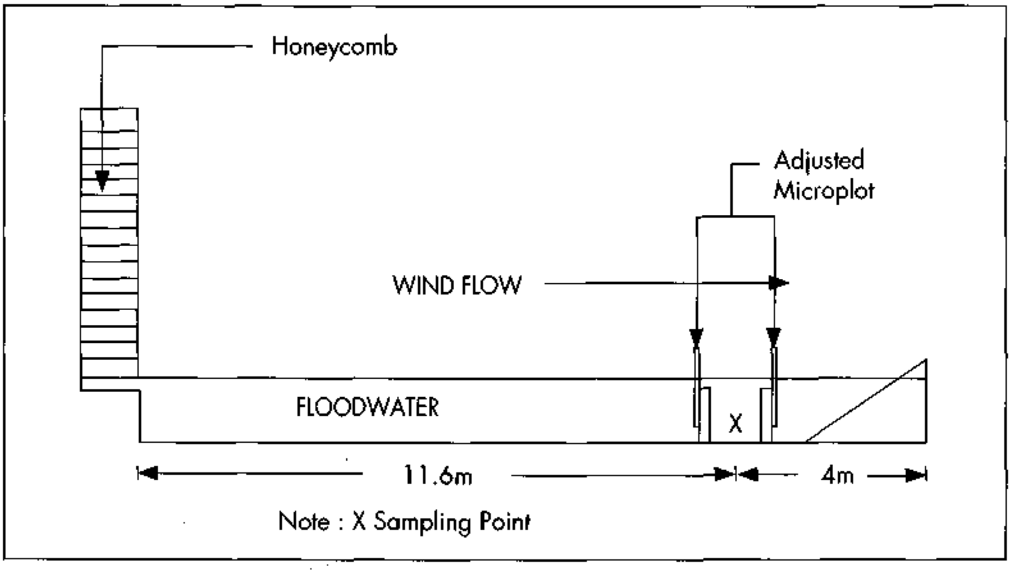

Fig. 2 Schematic Representation of Test Section with Microplot

Samples were collected by pipe tapped into 250ml dark colour bottles. The bottles were capped immediately by using a small glass funnel to the mouth of the bottle and stored. Initial samples were taken at every hour for the first 6 hours, then every 3 hours for twelve hours followed by only once for every 4 hours.

The date, time, location of sample taken, dry and wet temperature were recorded on the label attached to the bottle. The same information was recorded and entered in the log-file in sub-directory C: /ANALYSI/FLUX in the computer provided. The samples were then analysed for ammoniacal-N concentration using automated indophenol blue method.

RESULTS

Data on the parameters that affect NH_3 volatilization were taken. These include ammonium concentration, pH and temperature which determine the NH_3 (aq) concentration of floodwater, and data on the depth of flood water, temperature and wind speed which affect the volatilization rate k values across the water-air interface. The results are tabulated in Table 1. Table 2 lists out the collected data on a representative set for the pH, temperature and absorbance values for a particular rim height.

Table 1 Losses (%), Volatilization Rate (k) and Initial NH_3 concentration (C_o)

Runs	Rim height (cm)	Wind Speed (m/s)	Losses (percent)	k	NH_3-N concentration (C_o) (mo 1/m^3)
Run #4	3	2	63.4	3.35E-04	16.84
Run #3	3	4	71.61	4.20E-04	13.3370
Run #8	5	2	66.4	3.63E-04	25.3160
Run #9	5	4	77.42	4.96E-04	24.0450
Run #10	5	5	78.09	5.06E-04	18.9960

Table 2 Collected Data on pH, Temperature and Absorbance for a rim height of 3cm

Time(min)	pH value			Temperature (°C)	Absorbance		
0	8.26	8.25	8.26	26.3	0.533	0.537	0.543
60	8.23	8.24	8.25	26.5	0.520	0.517	0.525
130	8.23	8.24	8.25	26.7	0.512	0.507	0.509
240	8.23	8.24	8.24	26.6	0.5	0.509	0.515
360	8.22	8.23	8.23	26.6	0.494	0.499	0.501
480	8.20	8.23	8.23	26.1	0.483	0.477	0.491
660	8.18	8.22	8.22	26.0	0.472	0.471	0.476
840	8.16	8.16	8.22	25.3	0.461	0.463	0.467
1080	8.09	8.14	8.14	25.0	0.455	0.450	0.453
1260	8.06	8.13	8.13	25.2	0.443	0.441	0.447
1440	8.04	8.10	8.11	25.5	0.421	0.425	0.429
1675	8.02	8.08	8.08	26.0	0.401	0.409	0.413
1920	7.99	8.05	8.07	25.9	0.392	0.398	0.403
2160	7.96	8.01	8.05	25.7	0.386	0.390	0.397
2520	7.96	8.01	8.03	24.7	0.381	0.389	0.385
2760	7.9	7.95	7.95	25.0	0.370	0.379	0.374
2875	7.88	7.89	7.88	25.0	0.362	0.359	0.365

DISCUSSION

The rate of ammonia volatilization is high at higher wind speed as can be observed from Figure 3 which shows the comparison of ammonia concentrations at various wind speed with rim heights equal to 3 and 5cm. Referring to these figures and the k values in Table 1, it can be observed that with the increase in wind speed, the ammonia volatilization rate, k also increases. The higher the k values, the greater the transfer of NH_3 across the air-water interface.

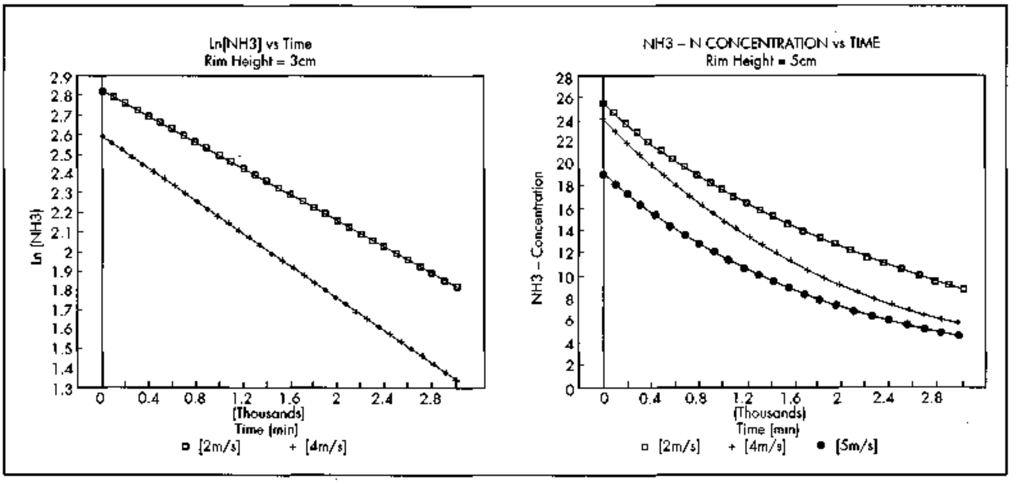

Fig. 3 Ammonia Concentration versus time for rim heights of 3 and 5cm

From Table 2 it is clear that ammonia volatilization is dependent on pH. The pH will decrease when the intensity of ammonia in flood water decreases. Table 2 represents one of the results of a series of model runs on various rim heights, wind speeds, pH and ammonia volatilization which were conducted. The models runs indicated that the pH has the capability of increasing NH_3 (aq) in floodwater by increasing the dissociation at high pH values and that a decrease in ammoniacal-N concentration is consistent with a drop in pH values.

The depth of floodwater was fixed at 24cm and the rim heights at 3 and 5cm. Depth of floodwater is also a major factor in ammonia loss because shallow water depth causes an increasing rate of ammonia volatilization but in this study this effect is not considered. Temperature is a parameter used in calculating the vapour pressure of NH_3 in floodwater. It ranges from 24.7°C to 28.3°C. Temperature will decrease when ammonia was added to the floodwater.

The wind tunnel experiments showed that large urea losses may occur, especially when windy conditions occur after the urea has hydrolized. It was found that 30 to 50% of the urea may be lost under unfavorable conditions.

Although other factors, such as daily temperature fluctuations and algae, also play an important role, they are difficult to simulate in a wind tunnel and are best studied in the field.

Some graphical representations of the results from the wind tunnel experiment on floodwater ammonia concentration are depicted in the Appendix.

CONCLUSION

The wind tunnel experiment have shown that the ammonia in floodwater, NH_3 (aq), is governed by ammoniacal-N concentration in the floodwater, the pH and the temperature. Ammoniacal-N concentration directly influences the floodwater NH_3 (aq), whereas pH and temperature influence the NH_3(aq) through fraction of dissociation of ammoniacal-N. The higher the NH_3 (aq) in floodwater the greater is the volatilization rate of NH_3 and NH_3 loss. A high wind speed increases the ammonia volatilization (k) value thus increasing the amount of NH_3 loss especially when windy conditions occur after the urea has hydrolized.

Acknowledgement

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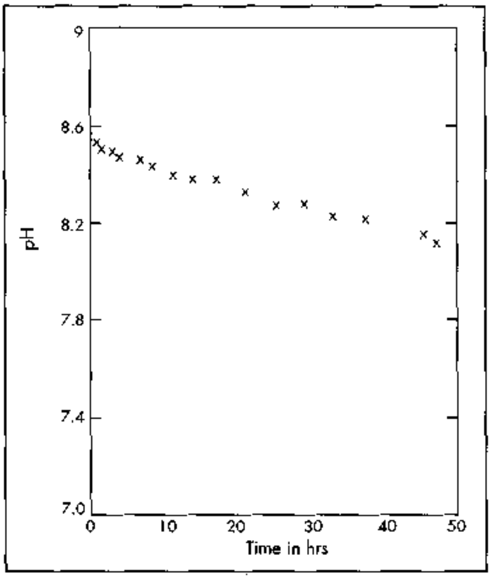
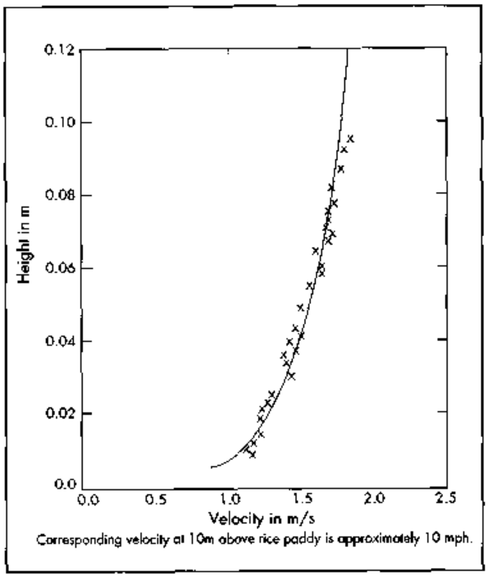
APPENDIX

Samples of data collected in the wind tunnel are shown below:

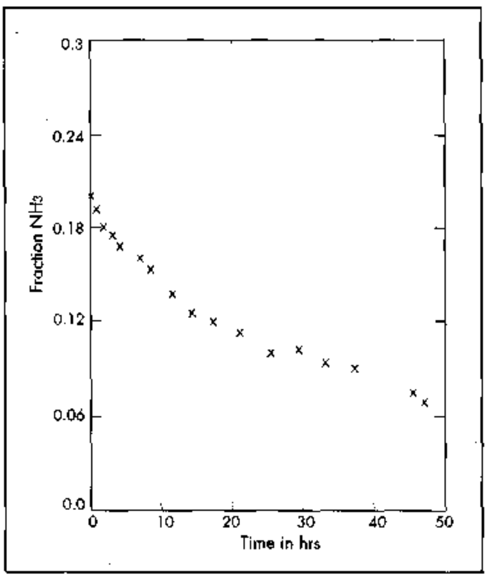
The pH decreases as a result of ammonia volatilization



Velocity measurements above the water surface at the downwind end of the wind tunnel



Ammonia concentrations decrease relative to the total ammoniacal nitrogen concentration in the water



Percent loss of nitrogen during the first 48 hours