THE EFFECT OF ANHYDROUS AMMONIA ON SASKATCHEWAN SOILS

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I. INTRODUCTION

The availability and use of anhydrous ammonia (NH_3) as a nitrogen (N) fertilizer has expanded rapidly during the past eight years in Saskatchewan. Along with its introduction to new areas came rumors that it had a damaging effect on the soil, that certain American or European soils had been ruined by the use of NH_3. Support or even specific sources for these rumors could not be found by correspondence with several agricultural scientists in the Central and Western United States. This was reported by Henry et al. (1979) in a review of the literature on the effect of NH_3 on soil. From their review and a later one (Tomasiewicz 1981) the following can be stated about the effects of NH_3 on soil:

a) NH_3 reacts physically (adsorption to surfaces) and chemically with the soil such that it is normally retained in a more-or-less cylindrical zone around the injection line. This zone is about 3-6 cm in radius, with NH_3 concentrations within it increasing as the injection line is approached. Thus, only a small portion of the soil is directly subject to the effects of NH_3 from an injection.

b) Initial reactions between NH_3 and soil result in a very slight warming effect along the injection line immediately after injection. This occurs despite the cooling effect of the NH_3 evaporation and expansion.

c) Soil pH is increased directly with the concentration of NH_3 present. Maximum pH values often exceed 9.

d) Retention zone soil is at least partially sterilized (organisms killed) by high pH and free NH_3 levels. Rates of recolonization vary widely among organism species. Heterotrophic activity, as indicated by CO_2 evolution, is retarded for a few to several days, followed by a period of stimulated activity.

e) The level of soluble organic matter is increased.

f) Plant roots will not grow into a zone of very high NH_3 content, and existing roots in such zones may be damaged.

g) The dispersing effect of the NH_4^+ ion and high pH may reduce structural stability and permeability. However, stability is increased beyond initial levels during nitrification, possibly in part due to re-precipitation of solubilized organic colloids.

h) The zone of maximum nitrifying activity is initially at the periphery of the NH_3 retention zone, and proceeds inwards. The process reduces soil pH to below untreated soil levels.

i) Levels of several plant nutrient ions in soil solution are
altered. These can mostly be attributed to pH changes and
cation exchange, and are not known to be of any agronomic
importance.

Of the above effects, we considered those most likely to be
damaging to the soil to be:

a) organic matter solubilization, possibly resulting in excessive
leaching loss or destabilization,

b) stimulated CO_2 evolution (organic matter loss via oxidation),
and

c) dispersion.

In fact, the rumors regarding harmful effects of NH_3 on soil often
mentioned organic matter destruction or "hardening" of the soil.

Since the review of Henry et al. (1979) the results of only a few
studies relevant to the subject have been found or reported. Nõmmik
and Nilsson (1963) reported the dissolution of soil organic matter
(SOM) by ammonium hydroxide in their study of NH_3 fixation by SOM.
Less than one percent of the total carbon (C) was water-soluble up to
about pH 9. Nemec and Vopenka (1971) found the extractability of soil
organic C to increase with increasing rates of NH_3, NH_4OH, $(NH_4)_2SO_4$,
and NH_4NO_3. NH_3 clearly had the greatest effect, especially
at high N rates. However, even at 800 ppm NH_3-N the level of water-
extractable C was only about 100 ppm (c.f. 40 ppm in untreated soil).
Ammonia also increased the extraction of major soil cations, but had
similar or less effect than the ammonium salts in this respect. Jadhav
et al. (1978) also measured general increases in soil solution ion
concentrations upon NH_3 addition.

A subject of recent concern is nitrite accumulation in parts of
the NH_3 retention zone during nitrification (Smith and Chalk 1980,
Bremner et al. 1981). Nitrite is very reactive chemically and subject
to loss via denitrification. Further work with realistic injection
techniques is required.

Ammonia concentrations around the injection line within a day after
field application of NH_3 to a range of Saskatchewan soils were reported
by Hogg and Henry (1982). The soil within 2.5 cm of the injection line
contained 200-800 ppm NH_3-N, and the levels were not clearly related to
specific soil properties. Ten to 200 ppm NH_3-N was present in the soil
2.5-5.0 cm from the injection line, while NH_3-N concentrations beyond
5.0 cm were similar to check soil levels. These data are useful in
relating results of the present laboratory study to field conditions.

A recent research project in Kansas addressed directly the question
of the effects on soils of continual long-term use of N fertilizers[1].
Anhydrous NH_3, ammonium nitrate, urea, and liquid N solution were each
used annually at high rates for ten years at three locations. After
the tenth harvest (1978) undisturbed soil samples were subjected to
measurements of several physical properties, such as aggregate stability

[1] L. Stone, personal communication. Kansas State University, Manhatten,
Kansas.

and penetrometer resistance. There were no significant differences among treatments (including a check treatment which received no N fertilizers). Organic matter levels (about 2.0-2.5%) were also unaffected. However, some soil chemical properties were influenced by the N fertilizers relative to those in the check plots. Inorganic N levels were higher. pH was 0.5-0.7 units lower, and there were some other changes that could be related to this, such as increased zinc and manganese availability. All four N sources affected soil chemical properties (and increased yield) similarly.

II. OBJECTIVES

Field work such as that described above was not undertaken, as it was felt that this could not produce valid conclusions in less than 8-10 years. Instead, the specific objectives were to:

a) quantify the solubilization of SOM by NH_3 for a wide range of arable Saskatchewan soils,

b) determine if NH_3 causes enhanced soil organic C oxidation (and therefore loss of oragnic matter via CO_2 evolution), and

c) observe, if present, the effect of NH_3 on soil physical conditions by study of the soil micromorphology in thin section.

In all cases NH_3 injections were made in the laboratory into large cylinders of undisturbed soil to simulate field conditions so much as possible. A preliminary study to illustrate nitrification and diffusion of NH_3 and nitrate (NO_3^-), as well as to test the soil sampling procedure, was also undertaken.

III. SAMPLING TIME STUDY

A. Materials and Methods

This test determined the effect of time between NH_3 injection and soil sampling on pH, nitrification, and water-solubility of SOM at four distances from the injection point. Cylinders of Carrot River soil similar to that described in Table 1 were used. They were collected by pressing aluminum pipe sections into the soil to remove undisturbed 20 cm diameter columns of soil (Fig. 1). Each of the 18 cylinders were injected with 0.834 g NH_3-N at a point centered within the cylinder and 10 cm below the soil surface (Fig. 1), with an apparatus designed after that of Smiley and Papendick (1968). Soil moisture was at about field capacity (FC; $\simeq 20\%_{odb}$) and injected cylinders were covered to reduce moisture loss.

At 1, 2, 4, 8, 15, 29, 53, and 122 days after injection pairs of cylinders were sampled in a concentric ring pattern according to the scheme shown in Fig. 2. Samples were sieved, mixed, and analyzed for gravimetric moisture, NO_3^--N, NH_4^+-N, pH (1:1 in water), and absorbance (A) @ 280 nm of the 1:20 soil:water extract. A @ 280 nm was used as an index of soluble organic C content. Organic C in the water extracts from two of the days was determined directly with a Beckman 915 Total Organic Carbon Analyzer.

Table 1. Characteristics of 0-15 cm depth samples.

Soil Association		1980[1] Land Use	O.M. (%)	Clay (%)	Texture	Lime	pH	Moisture (%)[2] PWP	FC
Melfort	M	Fallow	9.9	50	SiC	Abs.	6.1	22[3]	30
Sutherland	Su	Wheat	7.3	47	SiC	Abs.	7.2	10	34
Weirdale	We	Fallow	10.0	24	L	Low	7.8	9	28
Blaine Lake	B	Wheat	7.7	31	CL	Abs.	5.4	14	29
Tisdale	Ti	Rapeseed	5.4	27	SiL	Abs.	6.2	5	23
Bradwell	Br	Wheat	6.7	18	L	Abs.	7.2	5	23
Carrot River	Cr	Rapeseed	6.1	11	SL	Tr.	7.8	3	19
Weyburn	W	Fallow	3.6	21	L	Low	8.0	4	20
Arborfield	Ar	Barley	3.5	15	SiL	Abs.	7.0	4	18
Elstow	E	Wheat	2.6	19	SiL	Abs.	7.8	10	20
Asquith	A	Fallow	1.5	14	SL	Abs.	7.5	4	11
Meota	Me	Oats	2.7	9	LS	Abs.	7.0	2	10

[1] Soils taken in summer and fall of 1980

[2] Mean % H_2O_{odb} of samples taken from 7.5-12.5 cm depth after NH_3 injection. PWP values low due to partial air-drying after PWP reached in most cases.
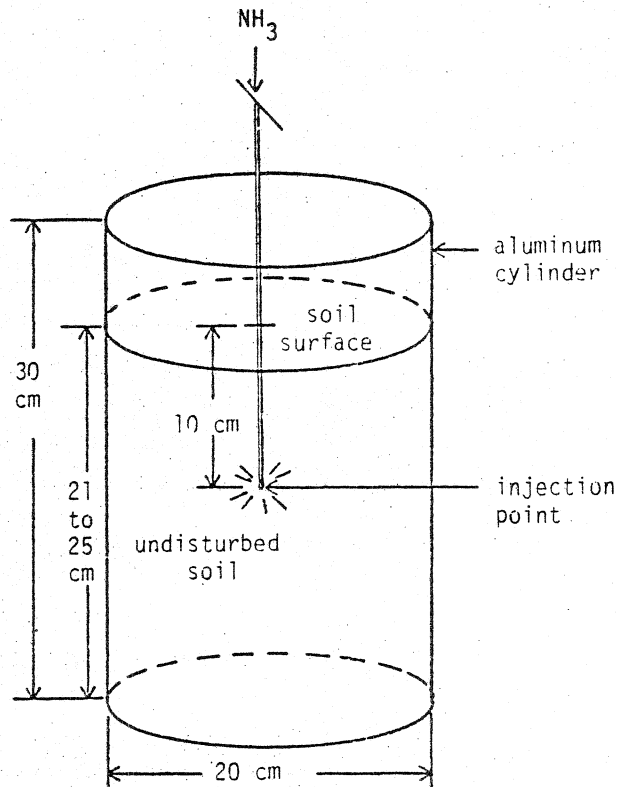
[3] Above PWP; this soil could not be injected at PWP.

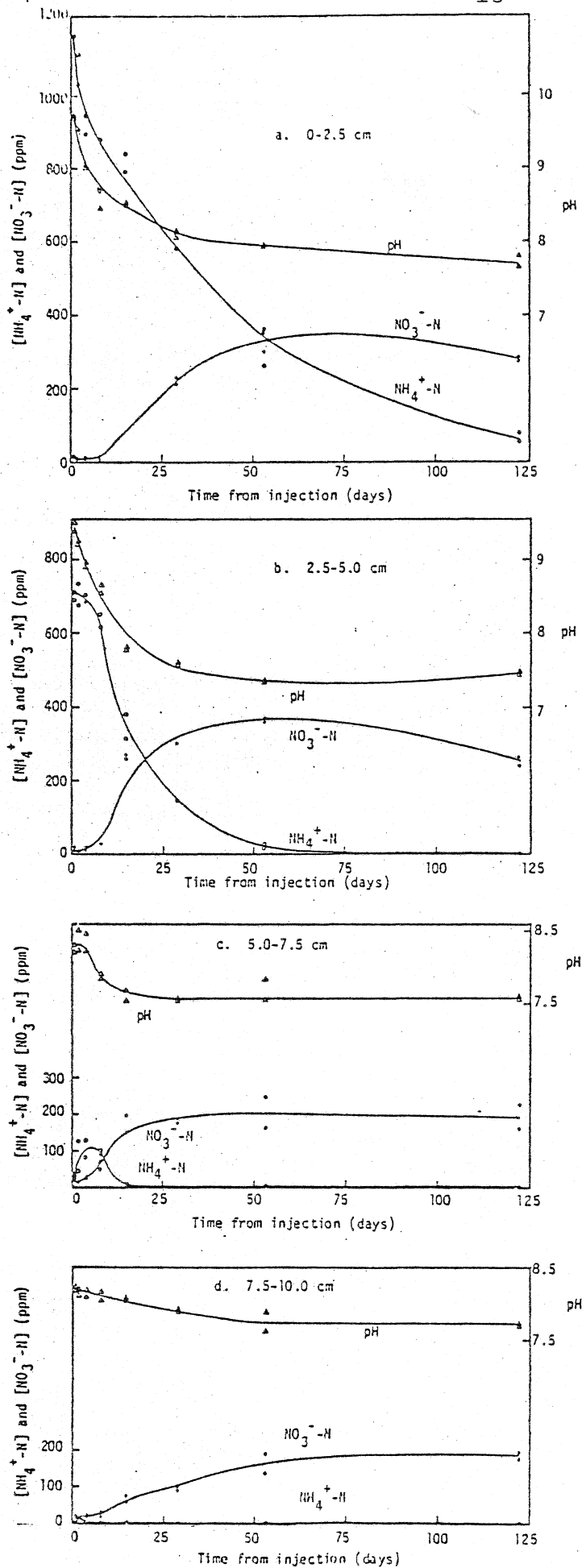Fig. 1. Diagram of injection of undisturbed cylinder of soil.

Fig. 2. Location and geometry of sampling of undisturbed cylinders
of soil.

B. Results and Discussion

The changes in NO_3^--N, NH_4^+-N, and pH levels for 122 days after
NH_3 injection are shown in Fig. 3 for the four sampling zones. The
progress of diffusion and nitrification are quite obvious. pH is
initially very high where the NH_3 is concentrated. It drops rapidly
in the two inner zones for several days while the NH_3 is diffusing
outwards. It continues to drop in all zones for several weeks to below
check soil pH (8.2) due to the acidifying effect of nitrification.
Concentrations of NH_4^+-N decrease and NO_3^--N increase with nitrification,
though NO_3^--N does not exceed about 400 ppm due to its diffusion. A
slight delay in nitrification in the central zone due to sterilization
is apparent.

Levels of water-soluble organic C were about 400 ppm in the outer
two zones and decreased slightly with time. However, they were at
about 1200 and 800 ppm for the first week in the 0-2.5 and 2.5-5.0 cm
zones, respectively. A reduction to near unaffected soil levels then
occurred, in much the same pattern as for NH_4^+-N.

The effectiveness of the sampling procedure in illustrating
conditions throughout the NH_3 retention zone suggested that it would be
appropriate for the larger study to be described next.

IV. SOIL ORGANIC MATTER SOLUBILIZATION STUDY

A. Materials and Methods

The distribution of NH_3 and extent of SOM solubilization one day
after point NH_3 injection in the laboratory were determined for twelve

Fig. 3. NH_4^+-N and NO_3^--N levels and pH in sampling zones of Carrot River soil to 122 days from injection of 0.834 g NH_3-N. (Horizontal distance from injection point stated).

cultivated Saskatchewan mineral soils varying widely in characteristics (Table 1).

Twenty large undisturbed columns of soil were taken at each site, as described in section III. A. Moisture was removed to the permanent wilting point (PWP) by growing wheat in them. Ten cylinders of each soil type were then used at PWP or drier (since some air-drying occurred before injection). The other ten were used two to six days after addition of sufficient water to wet the soil to FC to about the 20 cm depth.

For each soil type x moisture level combination (12 soils x 2 moistures = 24 combinations) eight cylinders were injected with NH_3 as described in section III. A. Two injections of 0.206 g NH_3-N, four of 0.416 g, and two of 0.834 g were used, corresponding to rates of 66, 132, and 265 kg N/ha based on the area of the cylinders. On the day after injection a check cylinder and two of each NH_3 rates were sampled as described in section III. A. The remaining cylinders (a check and two with 0.416 g NH_3-N) were covered to reduce moisture loss and sampled after 35-day incubation at room temperature. All analyses of the samples were also as described earlier, except a 1:15 soil:water ratio was used in the water extraction.

Organic C was determined directly by combustion in only ten or twelve of the water extracts from each soil. A linear relationship between organic C content and A @ 280 nm of the water extracts was then calculated for each soil. Organic C in remaining extracts was then estimated from A @ 280 nm and the appropriate regression. This was believed valid due to the close linear correlation between organic C content and A @ 280 nm (r ranged from .82 to .99, averaging .95, and the r value for only one soil was below .90).

B. Results and Discussion

The PWP and FC moisture contents of soil samples from injected columns are included in Table 1. FC moisture content was closely correlated (r = .92) with CEC as estimated from organic matter and clay contents.

The recovery of injected NH_3 as KCl-extractable NH_4^+-N was calculated for each injection. Average recovery varied from 74 to 113% for soils, and from 88 to 94% for NH_3 rates. The overall average was 91% ± 2 ($s_{\bar{x}}$). Some NH_3 volatilization during sampling and handling, and NH_4^+ fixation, probably occurred. Variability among percent recovery values was high (s = 24), possibly due to some failure of assumptions made in the calculations. A soil bulk density of 1.25 g/cm^3 was assumed, as well as equal NH_3 movement in all directions from the injection point.

For the 0.834 g NH_3-N injections, NH_4^+-N concentrations in the sampling zones the day after injection are graphed (Fig. 4). Only data from injections with 75-110% NH_3-N recovery are indicated. A relationship with soil properties is apparent. Ammonia retention is generally attributed to SOM, clay, and moisture. Higher NH_3 concentrations were present in the inner sampling zone(s) of soils high in these three fractions (especially if initially acidic), and concentration gradients were steeper. The maximum NH_3 concentrations encountered in each of twelve soils used was highly correlated with estimated CEC at FC moisture (r = .89).
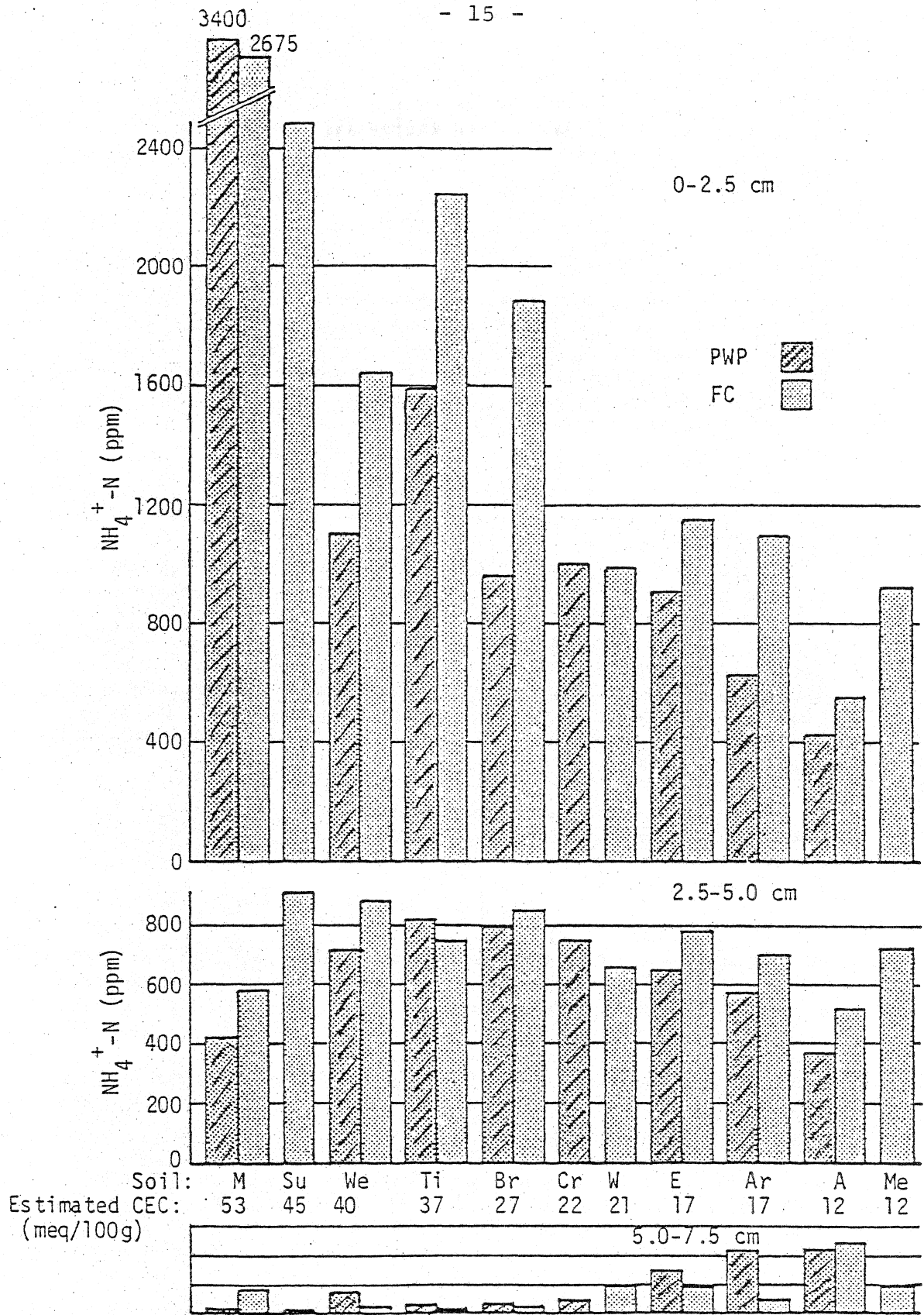
Fig. 4. Extractable NH_4^+-N content of soils sampled one day after injection of 0.834 g NH_3-N.

The NH_3 distribution at lower rates followed similar patterns. Increasing NH_3 rate resulted in increasing NH_4^+-N levels in the 0-2.5 cm zone, but also in a much larger proportion of the NH_3 moving out beyond that central zone.

The main objective of this study was to determine the amount of SOM solubilized by NH_3. Thus, levels of soluble organic matter in soils unaffected by NH_3 (i.e. in the 7.5-10.0 cm sampling zone and check soils) are noteworthy. The water extraction procedure used brought about 180-550 ppm of organic C (total oven-dry soil basis) into solution from the soils. This represented 0.4-2.2% of their total organic C, the proportion being generally higher for soils low in organic matter. Therefore, appreciable quantities of SOM were "soluble" by the criteria used even without NH_3 addition. The term "solubilized" organic C will refer to C removed by the water extraction in excess of that extractable from the 7.5-10.0 cm zone soil of the same soil column, i.e. to the amount of C made water-extractable by the effects of the NH_3.

Calculation of C solubilized by each NH_3 injection was possible, but was subject to quite large random variation in NH_3 recovery and soil variability among columns (recall that undisturbed soils were used). Instead, empirical relationships among NH_4^+-N, solubilized C, and pH increases (Δ pH) were calculated for each soil x moisture combination. The three variables were quite closely correlated by linear or quadratic equations. r^2 or R^2 values were mostly > .90, except for the Asquith soil in which there was a three week delay between soil sampling and analysis.

Within soil x moisture combinations (e.g. Meota FC) the Δ pH was found to be closely related to extractable NH_4^+-N by quadratic relationships. Only four of the twenty-four R^2 values were < .95.

Solubilized C could be related to NH_4^+-N concentration or Δ pH. It increased greatly with pH increases in the high pH range (8.5+), so the quadratic (curvilinear) relationships were most accurate (mean R^2 was .90). However, solubilized C was more consistently predictable from NH_4^+-N concentrations. The relationships were more linear in this case, not improving greatly upon going from a linear (mean r^2 = .92) to a quadratic (mean R^2 = .94) regression. Both are presented in Table 2. The quadratic relationships were used in subsequent predictions of C solubilization from NH_3 concentrations.

The maximum NH_4^+-N concentration from each soil x moisture combination, as well as the empirical relationships described above were used in calculation of the results in Table 3. The four NH_3 concentrations selected for each combination were 1, 2/3, 1/3, and 1/6 times the maximum observed in each case. These would include a level in the range of those found in the central part of the NH_3 retention zone from field studies (Hogg and Henry 1982), as well as at least one higher and one lower concentration in most cases. A 100 kg N/ha NH_3 application is assumed to be present at each of the four selected concentrations, and the resulting effects of it on pH, retention zone size, and C solubilization are predicted and tabulated. Each hypothetical situation is unrealistic in that NH_3 concentration

Table 2. Linear and quadratic regressions of concentrations of solubilized organic C (y) on KCl-extractable NH_4^+-N (x) [1]

Soil	Moisture	$y = a + bx$			$y = a + bx + cx^2$				Maximum $[NH_4^+$-N]
		a	b	r^2	a	b	C (x 10,000)	R^2	
Weirdale	PWP	-4	0.331	0.95	1.2	0.292	0.363	0.96	1135
	FC	-51	0.389	0.94	15.4	0.153	1.258	0.96	1900
Elstow	PWP	-13	0.188	0.92	5.2	0.054	1.397	0.94	940
	FC	18	0.239	0.85	15.1	0.255	-0.136	0.85	1200
Blaine Lake	PWP	-94	0.417	0.97	12.9	0.175	0.788	0.99	3050
	FC	-104	0.514	0.95	6.9	0.225	0.946	0.99	3200
Weyburn	PWP	1	0.128	0.93	5.7	0.100	0.267	0.94	990
	FC	11	0.239	0.90	-8.1	0.378	-1.286	0.92	1200
Asquith	PWP	-8	0.166	0.81	5.8	-0.039	4.289	0.90	480
	FC	-13	0.245	0.84	12.4	-0.007	4.109	0.90	580
Melfort	PWP	34	0.369	0.99	-3.3	0.512	-0.440	1.00	3400
	FC	-49	0.508	0.97	30.9	0.214	1.025	1.00	3200
Carrot River	PWP	17	0.140	0.91	8.1	0.208	-0.645	0.92	1020
	FC	-8	0.326	0.94	-0.1	0.274	0.408	0.95	1450
Arborfield	PWP	0	0.256	0.97	8.9	0.188	0.888	0.97	690
	FC	-26	0.456	0.96	-13.8	0.370	0.761	0.96	1105
Tisdale	PWP	14	0.404	0.97	1.7	0.469	-0.391	0.97	1850
	FC	16	0.432	0.89	2.4	0.473	-0.156	0.89	2700
Bradwell	PWP	18	0.251	0.79	2.8	0.360	-1.011	0.80	1150
	FC	1	0.448	0.91	-45.0	0.662	-1.300	0.93	1900
Meota	PWP	-4	0.471	0.99	11.0	0.319	1.971	0.99	760
	FC	-36	0.701	0.94	23.4	0.168	5.680	0.96	940
Sutherland	PWP	15	0.231	0.95	32.4	0.152	0.465	0.96	1850
	FC	-11	0.392	0.86	33.2	0.262	0.507	0.87	2800
$\bar{X}$		-11.5		0.92	6.9			0.94	

[1] Both in ppm_{odb}

Table 3. Organic carbon made soluble by 100 kg NH_3-N/ha in twelve Saskatchewan soils[2]

| Soil | Moisture | NH_4^+-N (ppm) | pH | Retention zone | | Solubilized organic C (ppm) | % of SOM solubilized | | Solubilized organic C (kg/ha) |
				% of HFS	Radius[1] (cm)		Retention zone	Total soil	
Melfort	PWP	3400	9.3	1	1.5	1229	2.14	0.031	36
		2267	8.7	2	1.8	931	1.62	0.036	41
		1133	7.5	4	2.6	520	0.90	0.040	46
		567	6.6	9	3.7	273	0.47	0.042	48
	FC	3200	9.0	2	1.6	1765	3.07	0.048	55
		2130	8.5	2	1.9	954	1.66	0.039	45
		1067	7.3	5	2.7	376	0.65	0.031	35
		533	6.5	9	3.8	174	0.30	0.028	33
Sutherland	PWP	1850	9.6	3	2.0	470	1.11	0.030	25
		1233	9.3	4	2.5	289	0.68	0.028	23
		617	8.5	8	3.5	144	0.34	0.027	23
		308	8.0	16	5.0	84	0.20	0.032	27
	FC	2800	9.7	2	1.7	1164	2.74	0.049	42
		1867	9.3	3	2.0	699	1.65	0.044	37
		933	8.5	5	2.9	322	0.76	0.041	34
		467	7.9	11	4.0	166	0.39	0.042	36
Weirdale	PWP	1135	9.6	4	2.6	379	0.65	0.029	33
		757	9.4	7	3.2	243	0.42	0.028	32
		378	8.8	13	4.5	117	0.20	0.027	31
		189	8.5	26	6.4	58	0.10	0.026	31
	FC	1900	10.0	3	2.0	760	1.31	0.034	40
		1267	9.3	4	2.5	411	0.71	0.028	32
		633	8.7	8	3.5	163	0.28	0.022	26
		317	8.3	16	4.9	77	0.13	0.021	24
Blaine Lake	PWP	3050	8.9	2	1.6	1280	2.86	0.047	42
		2033	8.2	2	1.9	694	1.55	0.038	34
		1016	6.9	5	2.7	272	0.61	0.030	27
		508	6.1	10	3.9	122	0.27	0.027	24
	FC	3200	8.9	2	1.6	1696	3.79	0.059	53
		2133	8.5	2	1.9	917	2.05	0.048	43
		1067	7.3	5	2.7	354	0.79	0.037	33
		533	6.4	9	3.8	154	0.34	0.032	29
Tisdale	PWP	1850	9.5	3	2.0	736	2.34	0.063	40
		1233	9.1	4	2.5	521	1.66	0.067	42
		617	8.0	8	3.5	276	0.88	0.071	45
		308	7.1	16	5.0	143	0.45	0.074	45
	FC	2700	9.7	2	1.7	1166	3.71	0.069	44
		1800	9.3	3	2.1	803	2.56	0.071	45
		900	8.2	6	2.9	416	1.32	0.074	46
		450	7.3	11	4.1	212	0.68	0.075	47
Bradwell	PWP	1150	9.5	4	2.6	283	0.73	0.032	25
		767	9.1	7	3.2	219	0.56	0.037	29
		383	8.5	13	4.5	126	0.32	0.042	33
		192	8.1	26	6.3	68	0.17	0.046	36
	FC	1900	9.8	3	2.0	744	1.91	0.050	39
		1267	9.5	4	2.5	585	1.50	0.059	46
		633	8.7	8	3.5	322	0.83	0.065	51
		317	8.2	16	4.9	152	0.39	0.061	61

[1] Radii given for 30 cm shank spacings. For 40 cm spacings, values would be 1.15X greater
[2] Predicted

Table 3. Continued

Soil	Moisture	NH_4^+-N (ppm)	pH	Retention zone		Solubilized organic C (ppm)	% of SOM solubilized		Solubilized organic C (kg/ha)
				% of HFS	Radius[1] (cm)		Retention zone	Total soil	
Carrot River	PWP	1020	10.0	5	2.7	153	0.43	0.021	15
		680	9.9	7	3.4	120	0.34	0.025	18
		340	9.3	15	4.7	71	0.20	0.030	21
		170	8.9	29	6.7	42	0.12	0.034	24
	FC	1450	10.2	3	2.3	483	1.36	0.047	33
		967	9.9	5	2.8	303	0.85	0.044	31
		483	9.2	10	4.0	142	0.40	0.041	29
		242	8.8	21	5.6	69	0.19	0.040	28
Weyburn	PWP	990	10.0	5	2.8	131	0.53	0.032	13
		660	9.7	8	3.4	83	0.40	0.030	13
		330	9.1	15	4.8	42	0.20	0.030	13
		165	8.7	30	6.8	23	0.11	0.033	14
	FC	1200	10.2	4	2.5	260	1.24	0.052	22
		800	10.0	6	3.1	212	1.01	0.063	26
		400	9.4	12	4.4	122	0.59	0.073	31
		200	9.0	25	6.2	62	0.30	0.074	31
Elstow	PWP	940	9.5	5	2.8	179	1.19	0.063	19
		627	9.4	8	3.5	94	0.62	0.050	15
		313	9.0	16	4.9	36	0.24	0.038	11
		157	8.6	32	7.0	17	0.11	0.036	11
	FC	1200	9.7	4	2.5	302	1.99	0.083	25
		800	9.4	6	3.1	210	1.39	0.087	26
		400	9.0	12	4.4	115	0.76	0.095	29
		200	8.7	25	6.2	66	0.43	0.108	33
Arborfield	PWP	690	9.2	7	3.3	181	0.89	0.064	26
		460	9.1	11	4.1	114	0.56	0.061	25
		230	8.5	22	5.8	57	0.28	0.061	25
		115	8.1	44	8.2	32	0.16	0.068	28
	FC	1105	9.6	5	2.6	488	2.40	0.108	44
		737	9.2	7	3.2	300	1.47	0.100	41
		368	8.5	14	4.6	133	0.65	0.089	36
		184	8.1	27	6.4	57	0.28	0.076	31
Asquith	PWP	480	9.1	10	4.0	86	0.98	0.103	18
		320	9.0	16	4.9	37	0.43	0.067	12
		160	8.7	31	6.9	10	0.12	0.038	7
		80	8.5	63	9.8	5	0.06	0.039	7
	FC	580	9.2	9	3.6	147	1.68	0.145	25
		387	8.9	13	4.4	71	0.81	0.106	18
		193	8.6	26	6.3	26	0.30	0.078	14
		97	8.5	52	8.9	16	0.18	0.092	16
Meota	PWP	760	9.4	7	3.2	367	2.34	0.154	48
		507	9.1	10	3.9	223	1.42	0.140	44
		253	8.0	20	5.5	104	0.67	0.131	41
		127	7.2	40	7.8	55	0.35	0.137	43
	FC	940	9.4	5	2.8	683	4.35	0.232	73
		627	9.1	8	3.5	351	2.24	0.179	56
		313	8.0	16	4.9	132	0.84	0.134	42
		157	7.2	32	7.0	64	0.41	0.129	41

[1]Radii given for 30 cm shank spacings. For 40 cm spacings, values would be 1.15 X greater.

is not uniform throughout the retention zone after field injection. However, results from all four concentrations used should give an impression of the differences along the NH_3 gradient. Assuming only one particular concentration gradient for each soil would be equally unrealistic in light of the many factors that influence NH_3 distribution after field injection (e.g. tilth, injector design).

In all example situations (Table 3) only a very small part of the total SOM to the 15 cm depth was made water-extractable by the 100 kg/ha of NH_3-N -- .021-.232%. Values considerably over 0.1% were calculated only for two sandy low organic matter soils. These proportions of SOM "solubilized" are small in comparison to those which can be "lost" altogether due to other effects such as erosion or microbial oxidation over a fallow year. The conversion to a kg/ha basis puts the amounts solubilized in perspective (Table 3). They are less than the amount of organic C in about 100 lbs of straw per acre. These proportions of SOM solubilized were the major concerns of the study -- they were very low in all soils, and this should be kept in mind as results are discussed further.

The proportion of the SOM in the retention zone alone that was solubilized was often considerable at high NH_3 concentrations (Table 3). It was 1.2-4.4% at the maximum FC NH_4^+-N concentration for all twelve soils.

In about half of the soil x moisture combinations the SOM solubilization per unit of NH_3 was similar at all NH_3 concentrations from 1/6 maximum to maximum, i.e. doubling NH_3 concentration approximately doubled the concentration of solubilized C, and so on. Therefore, knowledge of NH_3 distribution in the soil was not important in estimating C solubilization from any given injection rate. In soil x moisture combinations in which total SOM solubilization was affected by assumed NH_3 concentration, even the six-fold difference in NH_3 concentration resulted in less than a two-fold change in solubilized C (except for Asquith PWP).

Equal NH_3 concentrations in the soil tended to cause greater C solubilization in the FC soil than in the PWP soil (except in the Melfort and Weirdale soils). This was taken as evidence that a considerable to large proportion of the C solubilized by NH_3 was from killed soil organisms. Microbial biomass should have been high under the FC conditions in this study. Voroney (1979) increased extractable soil organic C considerably by chloroform fumigation. Zrazhevskiy and Seryy (1969) found the effects of NH_3 on soil similar to those of a sterilant in several respects.

The initial soil pH and SOM content tended to affect C solubilization by NH_3. Acidic soils underwent much greater pH change upon NH_3 treatment, and more C was solubilized. The chemical destabilization (e.g. change in colloidal charge) was probably greater than in soils already in equilibrium at an alkaline pH. The amount of SOM solubilized tended to increase with SOM content, while the proportion solubilized decreased. The higher proportion of the more chemically resistant SOM fractions in high organic matter soils may be involved.

Data from the samples taken 35 days after injection are not presented, but the general observations from them were as noted below.

After incubation at PWP:

a) the pH increase due to any given NH_3 concentration was less than that one day after injection by up to about one unit.

b) soluble organic C levels were not consistently affected by the extended incubation.

c) nitrification had not occurred, as indicated by unchanged nitrate levels.

d) concentrations of NH_4^+-N in the 0-2.5 cm zone decreased about 100-400 ppm, while those in the 5.0-7.5 cm zone increased, due to diffusion.

After 35 days at FC:

a) 3-68% of the injected NH_3 was still present as NH_4^+-N. The rest had nitrified to NO_3^--N. Only in the two coarsest textured soils was nitrification <80% complete.

b) pH decreases (to below check soil levels) and high NO_3^- levels due to nitrification were obvious throughout all sampling zones, with the exception of the 0-2.5 cm zones of very low CEC soils.

c) levels of soluble organic C in check soils had decreased.

d) only in a few samples with pH still elevated due to NH_3 were soluble C levels still above check levels. Reduced soluble C was more commonly observed.

V. CARBON DIOXIDE EVOLUTION STUDY

The Blaine Lake soil (see Table 1) was used to measure the effect of NH_3 injection on subsequent CO_2 evolution from undisturbed columns of soil. It was wetted to FC and preincubated before application of treatments. They consisted of (each in duplicate):

i)   blank - no soil
ii) check - no added N
iii) 0.282 g NH_3-N
iv) 0.619 g NH_3-N
v)   0.282 g urea-N (spot placed 10 cm deep)

The entire cylinders of soil were placed in air-tight plastic pails with NaOH solution to absorb CO_2. Unreacted base was titrated at intervals of from one day increasing to one week, for twenty weeks. The failure of the base to absorb all CO_2 evolved (due to the geometry of the system) necessitated the use of a correction factor and reduced the accuracy of determination of evolved CO_2 for the first few days.

Evolution of CO_2-C from the check cylinders of soil gradually decreased from about .9 to .6 mg/hr over the measurement period, with only a bit of "flutter" (± < 15%) during the first week due to the measurement problems. Release of CO_2 from the NH_3 - treated cylinders

was slightly retarded for a few days, then noticeably enhanced (reaching about 1.3 mg/hr maximum) to about 15-20 days. The urea treatment evolved a large flush of CO_2 during the first ten days due to hydrolysis of the chemical $[CO(NH_2)_2 + H_2O \rightarrow CO_2 + 2(NH_3)]$, and after this showed a pattern similar to the check soil. All treatment effects appeared to have passed by about three weeks, after which all treatments showed similar gradual slow declines in CO_2 evolution rate.

To assess the overall treatment effects a baseline or "no treatment" cumulative CO_2 evolution to 42 days was calculated for each soil cylinder, based on the 5-12 week evolution rates (Table 4). This was then compared to the observed CO_2 evolution to 42 days, the "difference" values indicating the increased CO_2 evolved due to the treatments. These values were small for the checks, and should have been 0 if all assumptions and techniques had been accurate. They were of about the right magnitude in the urea treatment to be accounted for by the C in the urea itself. Ammonia treatment caused a definite net increase in CO_2 evolution, greater at the higher rate. However, even at that rate (equivalent to 197 kg NH_3-N/ha) the increase in CO_2-C loss was <50 kg/ha. Again, the sterilizing effect of NH_3 may be responsible (c.f. flush of CO_2 after soil fumigation).

Table 4. CO_2 evolved from undisturbed cylinders of soil to 42 days from treatment.

| Treatment | Replicate | Cumulative CO_2-C evolution (mg) | | |
		Observed	Estimated for no treatment	Difference
Check	1	890	879	11
	2	866	834	32
Low NH_3	1	1038	976	62
	2	973	904	69
High NH_3	1	862	749	113
	2	960	816	144
Urea	1	1007	875	132
	2	983	826	157

VI. MICROMORPHOLOGY STUDY

The micromorphology study consisted simply of examination of soil thin sections prepared from NH_3 retention zones of laboratory-injected undisturbed soils. The first set of sections were prepared from NH_3 retention zone and check soils sampled three days after injection. No treatment effects were apparent in thin section.

A second set of sections were prepared from an injected Weirdale soil (described in Table 1). After injection at two NH_3 rates the cylinders of soil were subjected to leaching for a month with 50 cm of water in total. Samples were then taken for thin section preparation

and analysis. A very localized effect of NH_3 was apparent under high magnification in these sections. The small (<100 μ) silt-clay-organic matter micro-aggregates making up this soil were slightly more dispersed near the center of the NH_3 retention zone. This was believed due to a reduction in their water stability upon NH_3 treatment, an effect that has often been noted on a macro scale. Unfortunately, the resin in the center of the high rate NH_3 (0.834 g N) retention zones failed to harden properly, so sections could not be prepared from these areas.

VII. CONCLUSIONS

Ammonia retention and resulting SOM solubilization were studied in 12 undisturbed cultivated Saskatchewan mineral soils. One day after injection of NH_3 the highest NH_3-N concentrations around the injection point (>1000 ppm) were associated with soils high in SOM, clay, and moisture, and acidic soils. Soil pH and organic matter solubility were increased in relationship to the NH_3 concentration for each soil. A hypothetical application of 100 kg NH_3-N/ha was predicted to solubilize less than 75 kg/ha of organic C in all soils used. However, within the retention zone up to about 4% of the SOM could be made water-extractable. The sterilizing effect on soil organisms was believed responsible in part. Nitrification reduced pH and soluble C to or below the check soil levels.

Injection of NH_3 was also found to slightly increase CO_2 evolution. Again, possible SOM losses by this mechanism were insignificant (<50 kg C/ha due to 200 kg/ha NH_3-N injection).

Analysis of soil thin sections indicated slight dispersion of retention zone micro-aggregate structure when NH_3 injection was followed by leaching.

The results of these and other reported studies suggest that NH_3 injection has no significant deleterious influence on soil use or quality.

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