MITIGATING AMMONIA EMISSION FROM BROILERS WITH FREQUENT LITTER AMENDMENT APPLICATION

by

Chongyang Lin

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Civil Engineering

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ABSTRACT

Litter amendments are widely used to reduce indoor ammonia (NH_3) concentrations in boiler houses. This study evaluated NH_3 mitigation efficiencies of three amendments: sodium bisulfate (PLT), active carbon (AC), and zeolite. Lab-scale batch experiments were carried out to investigate the adsorption characteristics of zeolite on NH_3 in Chapter 2. The effects of retention time, moisture content, and particle size of zeolite on NH_3 absorption characteristics were examined. The removal efficacies of NH_3 were determined by evaluating the breakthrough curves obtained at three different moisture levels (0, 5, and 10%) with two different retention times (0.73 and 1.29s). Two sizes of zeolite (mesh -14+40 and -8+40) were tested. All Pairs Tukey HSD multiple comparisons were used to compare the variables. Compared to large size of zeolite, small size of zeolite increases air resistance, but not NH_3 adsorption rate. As moisture level increases from 0 to 10%, the NH_3 adsorption rate is predictable to be smaller. Retention time is a significant ($p<0.05$) factor that influences NH_3 adsorption rate: 1.4 and 2.4 mg NH_3/g zeolite were obtained at 0.73 and 1.29 s retention time, respectively. Another study was conducted to evaluate the connection between litter water content and amendment application rate on NH_3 emissions from poultry litter (Chapter 3). At moisture levels of 20, 30, and 40%, three separate amendments of sodium bisulfate (PLT), active carbon, and zeolite under one control and three different application rates, were topically applied to broiler litter. The effect of litter water content (20, 30, and 40% moisture levels) and litter amendment application rate was evaluated on NH_3 emission from broiler litter. The PLT application significantly ($p<0.05$) reduced NH_3

emission from the litter during the first two weeks. NH_3 emission reduction efficiency of litter amendments increased with application rates. In comparison, the NH_3 emission reduction efficiency of the three litter amendments ranked as: PLT > Zeolite > active charcoal. Reapply periods were suggested based on different moisture level and different amendment application rate.

PLT and zeolite were further conducted in a laboratory study with birds raised in environmentally controlled chambers (Chapter 4). PLT and Zeolite were frequently applied on the litter with three different application strategy, PLT was applied with: 0(Ctrl), 244 g/wk-m^2 (weekly), 488 g/^{2}wk-m^2 (bi-weekly), and 244 g/m^2 for week 3 and 6 and 488 g/m^2 for week 5 (variable); zeolite was applied on two strategies: weekly-Z: 1464 g/wk-m^2; bi-weekly-Z: 2928 g/wk-m^2. Repeated application of PLT led to significant reduction in NH_3 emissions from broilers. No net NH_3 emission reduction was found with zeolite treatments. The NH_3 emission reduction rate with PLT treatments ranged from 59.5% to 100% during broiler grow out period and cumulated NH_3 emission reduction from all the three PLT treatment ranged from 89% to 95% (4 week average grow-out per flock). Both PLT and zeolite treatments showed no significant influence on production performances (body weight, feed conversion, and foot pad quality). Litter pH was decreased by PLT but not zeolite. NH_3 nitrogen level, organic and total nitrogen contents in the treated litter were higher while less nitrogen was emitted as NH_3. The laboratory-scale findings of emission reduction by the additives indicate that zeolite is not a good amendment in control NH_3 emission, at least no economic advantage compares with PLT.

Chapter 1

GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Ammonia (NH_3), due to its impact on ecosystems, is one of the eight criteria atmospheric pollutants in the United States (USEPA, 2013). Major impacts associated with atmospheric NH_3 and its deposition includes eutrophication, soil acidification, and aerosol formation both in national and regional. The health effects of NH_3 are well known. NH_3 can be rapidly absorbed in the upper airway of human respiratory system (Nahm, 2005). NH_3, also, is an odorant with irritant properties. According to the most recent estimates, the total NH_3 emission in the US is 4.36 million ton and 86.3% of the NH_3 emissions are coming from agriculture sources (USEPA, 2008). 56.20% of NH_3 emission from agricultural sector is from animal feed operations (AFOs), which not only impact environment but also impact the live production performance, animal health, and welfare. Air quality associated with AFOs continues to be a high-priority issue for the animal agriculture in the US. Within the last 5 years, 2008-2012, compared with emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) decreased 13.3% and 36.5% respectively, NH_3 emission decreased 1.0% (USEPA, 2013).

NH_3 volatilization stems from microbial decomposition of nitrogenous compounds, principally uric acid, from animal feed operations (Chang and Chang, 1999). NH_3 generation rate is related with micro bacteria activities, and microbe activities can be estimated by bacteria population density (Okano et al., 2004). To control the NH_3 emissions from AFOs, litter amendments have been used to treat broiler litter. The most wildly used amendment is acidifier. The equilibrium between NH_4^+ and NH_3 in aqueous systems at constant temperature is determined by pH value. Acidifier can decrease pH value and a lower pH leads to a lower proportion of aqueous NH_3 and, therefore, to a lower potential of NH_3 volatilization. Acidification of animal manure to mitigate losses of NH_3 relies on this basic principle (Ndegwa et al., 2008). Lower NH_3 concentrations and bacterial loads in broiler houses can also improve bird health and production (Terzich et al., 1998). Currently most litter amendments are only applied prior to chick delivery due to potential bird toxicity and hazardous exposure. Litter amendments have been tested holding the NH_3 flux well at the beginning of application, but at the end of the flocks, no much difference between treated and untreated houses was seen (Miles et al., 2008). However, information on the efficacies of multiple litter amendment application during broiler grow-out on broiler NH_3 mitigation is meager.

Flux chambers had been widely used for air quality and NH_3 emission studies in animal feed operations (Miles et al., 2008; Li and Xin, 2010). Fresh air or NH_3 free air is required for some of the flux chamber system, such as dynamic system. In large poultry operations, it could be inconvenience to carry a large zero gas cylinder or run a long tubing to bring fresh air from outside of the animal houses. An alternative method to generate NH_3 free air is using zeolite as filter media to capture NH_3 in air and use filtered air for flux chambers. This method could make the flux chamber be mobile and easily be deployed in the field and reduce the setup time. The adsorption property of filter media can be affected by retention time, gas concentration, moisture content, and particle size of the filter media. However, limited information is available for the characteristics of zeolite as a filter media on NH_3 adsorption rate and breakthrough point affected by retention time, moisture content, and particle size.

1.2 Objective

The objectives of this thesis are to assess the effects of retention time, moisture content, and particle size of zeolite on the absorption characteristics of gaseous NH_3 from poultry litter (Chapter 2), to compare different amendments (PLT™, zeolite and active charcoal) effective performance at different moisture levels (20, 30 and 40%) and different application rates in reducing NH_3 emission from poultry litter and give an optimize reapply frequencies (Chapter 3), and to quantify and delineate the efficacies of PLT and zeolite topically repeatedly applied at different rates on reduction of NH_3 emissions under commercial production conditions (Chapter 4).

1.3 Literature Review

1.3.1 Variable Methods in NH_3 Mitigation

Several methods have been studied and used in NH_3 emissions mitigation: 1) using new or alternative bedding materials for each broiler operation during each grow-out, 2) controlling and lowering litter moisture content, decrease bacteria activity and decrease NH_3 generation; 3) applying chemical additives that decrease manure pH, shift the equilibrium in favor of ammonium (NH_4^+) over NH_3, and bind NH_3, adsorbent additives that adsorb NH_3 on adsorbent; 4) Filtration using zeolite, active charcoal, bio-filters, scrubbers to treat exhaust air and remove NH_3 (Lau and Cheng, 2007). Gates et al. (2008) found using new bedding material decreased NH_3 emission by 27 – 47% compared with built-up litter. Another bedding material, 40 – 60% peat with straw mixture, was found decrease 57% NH_3 emission (Jeppsson, 1999). A lab scale study was conducted with compost medium and activated carbon as an added material, and NH_3 concentration reduced more than 95% (Liang et al., 2000). Another woodchips medium biofilter was reported to reduce NH_3 volatilization from 54 to 93% (Sheridan et al., 2002). Lahav et al. (2008) reported an acidic ($0<pH<5$) bubble column reactor, which can reduce 100% NH_3 emission. Vegetative environmental buffer was investigated by Adrizal et al. (2008) to capture NH_3 and decrease NH_3 emission and 78% NH_3 emission reduction was found downwind (Ndegwa et al., 2008; Patterson et al., 2008). Among all the methods, acidic litter additives are the most wildly used in poultry house. Acidifying and adsorbent have been proved potential exists to develop further practical and cost-effective additives (McCrory and Hobbs, 2001).

1.3.2 Zeolite in Adsorption and Mitigation of NH_3 from Poultry Operations

Zeolite NH_3 adsorption property is influenced by the type of zeolite, zeolite particle size, air retention time, zeolite moisture content and also NH_3 concentration or NH_3 partial pressure and so on. Zeolite sample from Teage Mineral Products was tested (Bernal et al. 1993a) and 6.3 - 14.2 mg N/g zeolite adsorption capacity was reported. With the same zeolite sample, Bernal et al. (1993b) found that moisture content of zeolite had a linear negative relation with NH_3 adsorption rate, as the water retention increase from 8.5 to 27.7%, the NH_3 adsorption decrease from 2.40 to 0.74 N mg/g in a composting simulator system. The possible reason is that adsorbed water blocked zeolite internal channels and impeded the NH_3 adsorption. In contrast, another type of zeolite from Chifeng, Inner Mongolia, China was investigated, with particle size increasing from 0.16 to 0.63 mm, particle surface area reduced and the adsorption capacity of NH_3 decreased. NH_3 adsorption capacity increases from 0.097 to 0.44 mg/g with water content increasing from 0 to 40% (Li et al., 2010). An ion exchange reaction was proposed with water existent. One type of zeolite obtained from Kenort Ltd, Shropshire (UK) was used in the composting of a sewage sludge-straw mixture for 14 days, and 6.5 mg N/g adsorption capacity was obtained (Witter and Lopez-Real, 1987). The retention time was found to have a positive influence on NH_3 adsorption; as retention time increases the physisorption increases (Ducourty et al. 1998).

The performance of zeolite in NH_3 emission mitigation in poultry operations was varied. A layer hen manure with 38% zeolite placed on the surface of the manure reduced NH_3 losses by 44% (Kithomie et al., 1999). Nakaue et al. (1981) reported modest reductions in NH_3 levels in the poultry house, while Amon et al. (1997) reported large increases in NH_3 levels when zeolite was applied to litter.

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Chapter 2

ADSORPTION CHARACTERISTICS OF ZEOLITE ON AMMONIA FROM POULTRY LITTER

2.1 Introduction

In 1756 Cronstedt, who was a Swedish mineralogist, first discovered a white transparent fossil in the almond shaped basalt pore, which was named zeolite for its foaming and boiling when heated. Zeolite is aluminosilicate mineral with water structure and a family of aluminosilicate mineral, the common minerals is natrolite, scolecite, analcime, clinoptilolite, mordenite and so on (Li et al. 2010). Natural clinoptilolite (zeolite) is a cation-exchange compound that has high affinity and selectivity for ammonium ion (NH_4^+) and also has good gas adsorption properties due to its porosity and high surface-area-to-volume ratio. It has been used as an amendment to poultry litter, in anaerobic digesters treating cattle manure, in composting of pig slurry and poultry manure, as an air scrubber material to improve poultry house environment, and as a filtration agent in deep-bedded cattle housing.

Zeolite NH_3 adsorption property is influenced by the type of zeolite, zeolite particle size, air retention time, zeolite moisture content and also NH_3 concentration or NH_3 partial pressure and so on. Zeolite sample from Teage Mineral Products was tested Bernal et al. (1993a) and 6.3 - 14.2 mg N/g zeolite adsorption capacity was reported. With the same zeolite sample Bernal et al. (1993b) found that moisture content of zeolite had a linear negative relation with NH_3 adsorption property, as the water retention increase from 8.5 to 27.7%, the NH_3 adsorption decrease from 2.40 to 0.74 mg N/g in a composting simulator system. The possible reason is adsorbed water blocked zeolite internal channels against the NH_3 adsorption. Another type of zeolite from Chifeng, Inner Mongolia, China was investigated by Li et al. (2010). With zeolite particle size increasing from 0.16 to 0.63 mm, particle surface area reduced and the adsorption capacity of NH_3 decreased. Another moisture influence theory was proposed: NH_3 adsorption capacity increase from 0.097 to 0.44 mg/g with water content increase from 0 to 40% moisture level. An ion exchange reaction was proposed with water existent. One type of zeolite obtained from Kenort Ltd, Shropshire (UK) was used in the composting of a sewage sludge-straw mixture for 14 days, and 6.5 mg N/g adsorption capacity was obtained. (Witter and Lopez-Real, 1987).The retention time was found to have a positive influence on NH_3 adsorption; as retention time increase the physisorption increase (Ducourty et al. 1998).

Flux chambers had been used widely for air quality and NH_3 emission studies in animal feed operations (Li and Xin, 2010; Miles et al., 2008). Fresh air or NH_3 free air is required for some of the flux chamber system, such as dynamic system. In large poultry operations, it could be inconvenience to carry a large zero gas cylinder or run a long tubing to bring fresh air from outside of the animal houses. An alternative method to generate NH_3 free air is using zeolite as filter media to capture NH_3 in air and use filtered air for flux chambers. This method could make the flux chamber be mobile and easily be deployed in the field and reduce the setup time. Breakthrough curve analyses is one of the most wildly used method in evaluate column contaminant remove (Cooney et al., 1999; Zheng et al., 2008; Liu and Lo, 2001; Gezici et al., 2006; Mthombeni et al., 2012). It has been used in column adsorption processes as obtaining amount of the adsorbed analyte, adsorb capacity and also adsorption property. The adsorption property can be affected by retention time, gas concentration, moisture content, and particle size of filter media. However, limited information is available for the characteristics of zeolite as filter media on NH_3 adsorption rate and breakthrough point affected by retention time, moisture content, and particle size.

The objective of this paper was to assess the effects of retention time, moisture content, and particle size of zeolite on the absorption characteristics of gaseous NH_3 from poultry litter.

2.2 Material and Method

Lab-scale batch experiments were carried out to investigate the adsorption characteristics of gaseous NH_3 from poultry manure by natural zeolite (BRZ ^{TM}, Bear River Zeolite, CO., INC., Preston, ID). BRZ™ is almost pure clinoptilolite with a general formula of (Na, K, Ca)$_{2-3}$Al$_3$(Al, Si)$_2$Si$_{13}$O·12H$_2$O (BRZ™, 2013). Many different sizes of zeolite were available as NH_3 filter media. Fine zeolite particles could capture more NH_3 due to its relative lager surface area. However, fine particles can create higher pressure drop and require higher capacity air pump to overcome the flow rate loss from it, which may limit it application while high flow rate is required. Based on the manufacturer's recommendation, two sizes were selected and investigated in the paper with consideration of pressure drop and adsorption efficiency (Table 2.1).

Table 2.1: Characteristics of the BRZ™ (A and B)

Parameter	A		B
Mess grade	-14+40		-8+40
Cation exchange capacity (mg NH_3 /gram)		23.8 to 28.1	
Nitrogen (as NH_3) loading capacity (%)		1.8-2.1	
Surface area (m^2/gram)		24.9	
Bulk density(kg/m^3)	881		961
Particle size(mm)	1.41 x 0.400		2.38 x 0.400
Specific gravity(water)		2.0-2.4	
Porosity	0.56-0.63		0.52-0.60

A column testing system was used to conduct the evaluation (Figure 2.1) by measuring flow rate and NH_3 concentration of air streams before and after columns with zeolite. The system was operated in an environmentally controlled room at 20 ± 2°C and 50 ± 15% relative humidity. Used broiler chicken litter with 22% moisture content was used to generate NH_3 in a 19-L container. NH_3 concentration in the container was controlled by changing the air exchange rate in the container. In this study, NH_3 concentration was set in the range of 20 to 200 ppm, which is similar to the concentration under field conditions in either broiler houses or laying hen houses, including manure belt and high-rise houses. The measurement system consists of six columns with zeolite and one bypass column without zeolite. An air compressor/vacuum pump pushed NH_3-laden air from the 19-L container into the seven columns with a constant flow rate of 1.4 LPM measured by air flow meter (RMB-49-SSV, Dwyer, Michigan City, India.). The air samples after each column were sequentially taken for 5 min per column by using three-way solenoid valves (6014, Christian Bürkert GmbH & Co. KG, Christian-Bürkert-Straße, Ingelfingen, Germany) and continuously monitored for 14 to 46 hrs. NH_3 concentration was measured with a photoacoustic multi-gas analyzer (model 1412, INNOVA AirTech Instruments A/S, Ballerup, Denmark). The outputs from the multi-gas analyzer were logged with one sec interval into a PC through serial communication port with a LabVIEW program (Version 2009, National Instrument, Austin, Texas). A relay module (EBR-24, Measurement Computing Corporation, Norton, MA) was driven by the LabVIEW program to control the solenoid valves. The average reading of last one minute over the 5 min sampling period of each column was used to calculate the adsorption rate and efficiency.

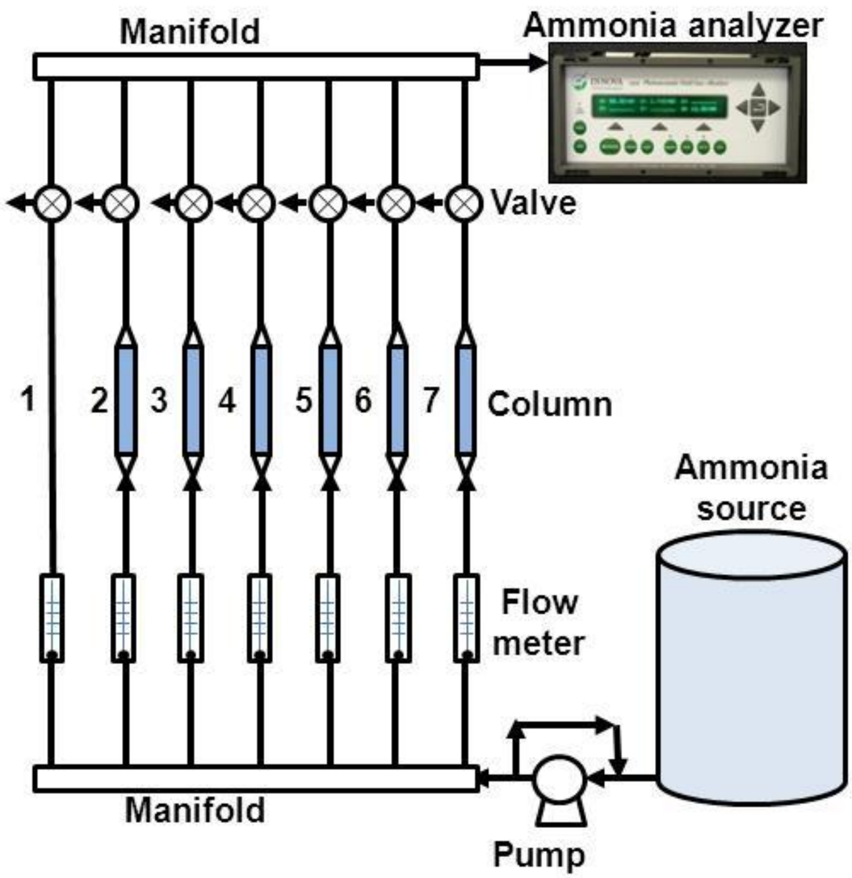


Figure 2.1: Schematic of the testing system

Prior to the experiment, the two sizes of zeolite were dried at 105°C in oven for 24 hours, and preconditioned in a sealed container. Deionized water was added into zeolite to achieve 5% and 10% (weight base) moisture content. For each batch test, zeolite with two particle sizes (-14+40 and -8+40) and three moisture content (0%, 5%, and 10%) was added into the six vertically placed columns (1.6 cm) diameter and constant air flow 1.4 LPM (Table 2.2). The retention time of zeolite column during each batch of test was the same (0.73 or 1.29

sec) by setting the column height (10.2 or 18 cm). For each treatment, there were three repeated testes.

Table 2.2: Operating conditions of zeolite columns in the flow-through study

Zeolite	A	B
Mesh grade	-14+40	-8+40
Diameter(cm)	1.6	1.6
Zeolite column height(cm)	10.2, 18.0	10.2, 18.0
Moisture level (%)	0, 5, 10	0, 5, 10
Air flow(L/Min)	1.4	1.4
Retention time(s)	0.73, 1.29	0.73, 1.29

It is critical to determine the pressure drop from zeolite filter column to assist selecting proper air pumps for flux chambers. The two sizes of dry zeolite were placed into two columns with 18 cm height. The pressure drops, differential pressure before and after the two columns were measured with four different air flow rates as 1.0, 1.2, 1.4 and 1.6 LPM by a differential pressure transducers (PX01S, Veris Industries, Tualatin, Oregon). Friction factor of zeolite and pressure drop from zeolite filter media in column can be expressed by using Darcy-Weisbach equation:

$$P \propto F \times \frac{L}{D} \times f(V) \qquad (1)$$

where,

V is air flow rate (L/min),

$f(V)$ is function of air flow rate,

P is differential pressure (Pa),

D is column diameter (m),

L is column length (m), and

F is friction factor of zeolite friction factor (kg/m).

When Eq.1 is simplified, the pressure drop is expressed in terms of air flow rate:

$$P \propto f(V) \tag{2}$$

The adsorption rate was calculated using air flow rate and concentration difference between inlet and outlet of each column:

$$Q = \sum_{i=0}^{t} (C_{i,t} - C_{o,t}) V/m \tag{3}$$

where,

Q is NH_3 adsorption rate (mg NH_3/g zeolite),

$C_{i,t}$ is inlet NH_3 concentration (mg/L),

$C_{o,t}$ is outlet NH_3 concentration (mg/L),

V_t is air flow rate under standard condition (LPM), and

m is the adsorbent weight (g).

NH_3 removal efficiency (RE) was determined by the equation:

$$RE(\%) = \frac{Co - Ci}{Ci} \times 100 \tag{4}$$

2.3 Statistical Analyses

Procedures of JMP Pro 10 (SAS Institute, Inc., 2013) were used in the following analyzing. NH_3 removal efficiency (%) for the three different moisture level, two different type of zeolite and two retention time were taken and compared by Tukey HSD and Student's t-test (JMP10, SAS Institute Inc., Cary, NC, USA) based on the NH_3 adsorption rate.

2.4 Result and Discussion

2.4.1 Pressure Drop Caused By Zeolite

The pressure drop from filter columns with the two sizes of zeolite is a polynomial function of air flow rate (Figure 2.2). Pressure drop increases while air flow rate is higher. Higher resistant from zeolite A was expected because of its smaller particle size and larger contact surface area compare to zeolite B. The pressure drops were 2147 and 1643 Pa (8.6 and 6.6 in. water) for zeolite A and B, respectively while the air flow rate was 1.4 LPM. The pressure drop from zeolite A was 28.8% to 35.1% higher than that from zeolite B when air flow rate changed from 1.6 to 1 LPM with 18cm column height and 1.6 cm diameter. The pressure drop is proportional to column height and diameter.

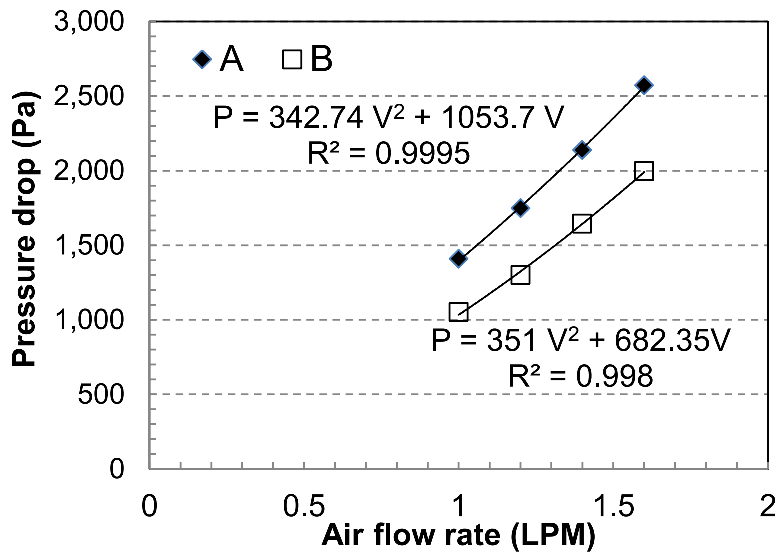
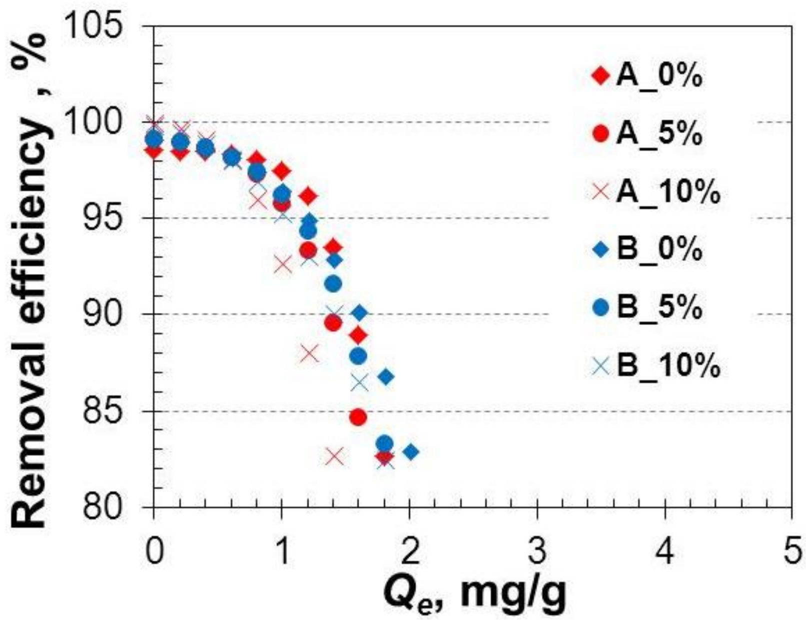


Figure 2.2: Pressure drop after A and B zeolite column

2.4.2 NH_3 Removal Using Continuous Flow Zeolite Columns

Experiments were carried out on the packed zeolite columns to determine the effects of zeolite particle size, moisture content level (0%, 5%, and 10%) and retention time on NH_3 removal efficiency and breakthrough curve.

From the breakthrough analysis (Weber et al., 1983, Bernal et al., 1993; Liu and Lo, 2001b; Mthombeni et al., 2012) and the fresh air needed in the flux chamber test, 90% RE is used as the column breakthrough point. Figure 2.3 shows the effects of three different moisture levels on RE and adsorption capacity with two different retention times. Different NH_3 adsorption rate was obtained from 1.1 to 1.6 mg N/g with 0.73 s and from 2.2 to 2.6 mg N/g with 1.29 s, and the RE was slightly lower at higher moisture level but not significant different ($P<0.05$) within each retention time. Similar result was seen that as zeolite moisture level increase from 8.5% to 27.7% NH_3 removal efficiency decrease significantly (Bernal et al., 1993b).



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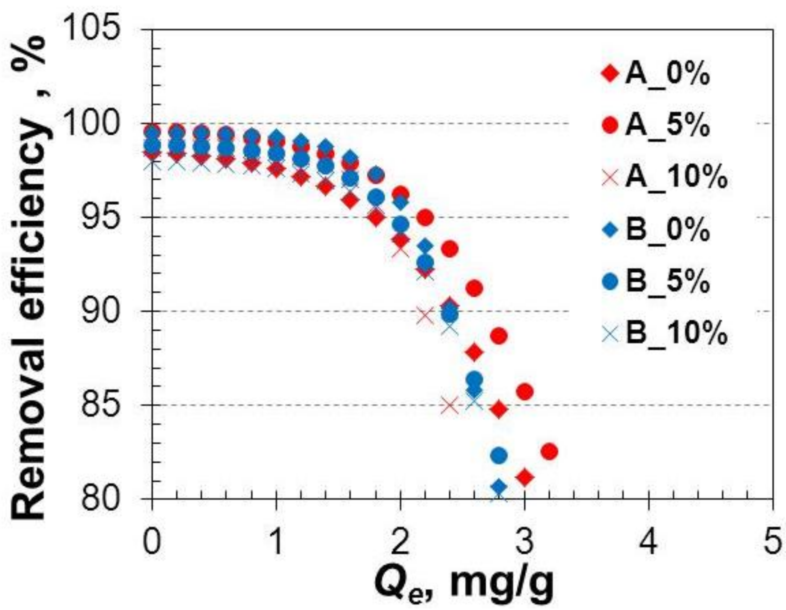
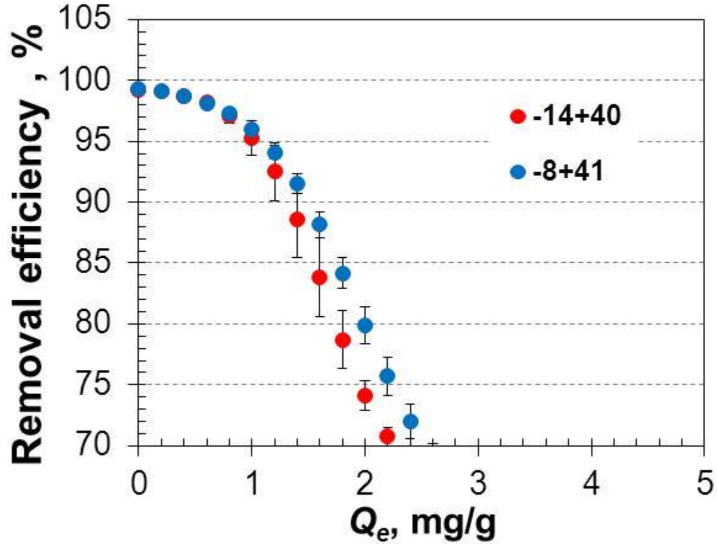


(b)

Figure 2.3: Comparison of NH_3 removal efficiency of zeolite with three different moisture levels (Retention time: a=0.73s, b=1.29s)

The three different moisture levels were pooled to test the zeolite particle sizes (A and B) influence on the NH_3 removal efficiency (Figure 2.4). A smaller zeolite particle size (0.16 vs. 0.63 mm) was found to have a greater NH_3 adsorption capacity due to a larger surface area

(Li et al., 2010). No significant difference was found at the breakthrough point (90% RE) for zeolite A and B (p-value > 0.1). NH_3 adsorption decreased as zeolite particle diameter increasing when particle size is less than 1 mm. However, there was no significant influence while zeolite particle size increased from 1.41 to 2.38 mm. Size B offers a better solution as NH_3 filter media than smaller size A due to its lower air resistant.



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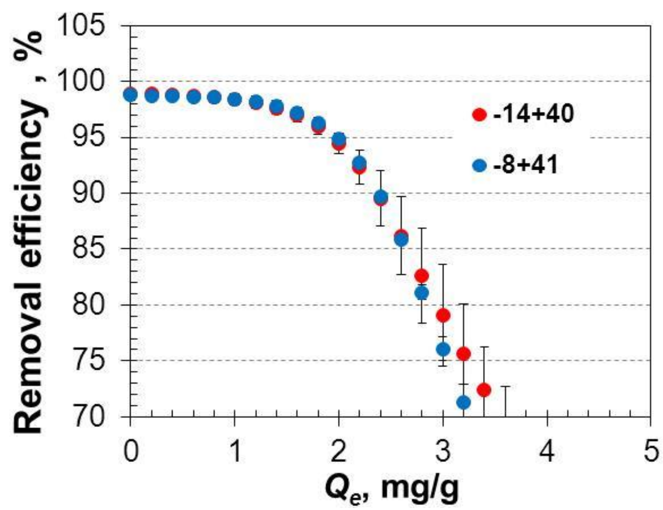

(b)

Figure 2.4: Comparison of NH_3 removal efficiency of zeolite with two different sizes(A:-14+40, B:-8+40) (Retention time: a=0.73s, b=1.29s)

Three different moisture levels (0%, 5%, and 10%) and two different zeolite particle sizes were pooled together to compare the air retention time influence to the NH_3 adsorption capacity based on the breakthrough point determined by removal efficiency (Figure 2.5). A significant (p-value < 0.0001) effect was found on different retention times. NH3 adsorption rates were 1.40 ± 0.18 and 2.38 ± 0.15 (mg/g NH_3/zeolite) at 90% RE points with 0.73 and 1.29s retention time, respectively. Higher NH_3 adsorption can be found with higher air retention time in Figure 2.4. Similar results were found by Li et al. (2010) and Bernal et al. (1993b) that NH_3 adsorption rate increased from 0.74 to 2.40 mg/g and 0.09 to 0.13 mg/g when retention time increased 2 and 8 times, respectively.

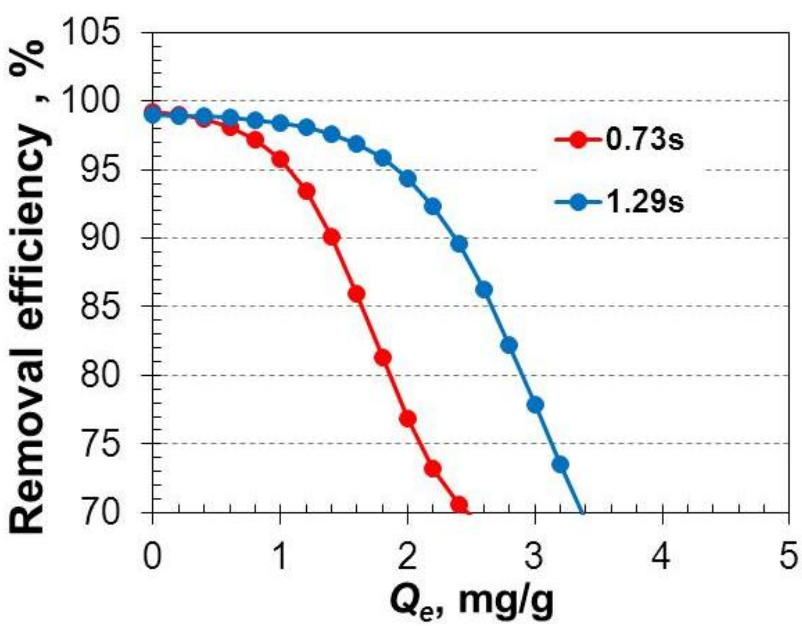

Figure 2.5: Comparison of NH_3 removal efficiency of zeolite with two different retention times (0.73 vs. 1.29 sec).

A regression equation between NH_3 removal efficiency (RE, %) and NH_3 adsorption rate (Q_e) at two different retention times was derived as shown:

$$RE = \theta_1 + \frac{\theta_2 - \theta_1}{1 + EXP[\theta_3 * (Q_e - \theta_4)]} \quad (5)$$

where θ1, θ2, θ3 and θ4 are constant for the two different retention times in Table 2.3.

Table 2.3: Removal efficiency vs. NH_3 adsorption rate prediction equation constant parameters

Retention time, sec	θ1	θ2	θ3	θ4
0.73	66.2	99.4	2.82	1.73
1.29	56.9	99.1	2.10	2.99

Table 2.4 shows NH_3 adsorption property from other similar studies. NH_3 adsorption capacity varied in a large range from 0.097 to 14.155 mg N/g. The main differences among these studies are moisture levels and retention times. Witter and Lopez-Real (1987), Witter and Kirchmann (1989), Bernal and Lopez-Real (1993a) and Li et al. (2010) were concentrating on NH_3 adsorption capacity at equilibrium condition. Highest NH_3 adsorption capacity (6.255 – 14.155 mg N/g) was found at 0% moisture level and followed by 4.8% moisture level. As moisture level increased to 20% to 60%, NH_3 capacity became 5 to 100 times smaller.

Table 2.4: Comparison of zeolite NH_3 adsorption rate

Zeolite source	NH_3 source	Moisture level (%)	NH_3 Capacity (mg N/g)	Reference
Natural zeolite	Sewage sludge composting	4.8	6.5	Witter and Lopez-Real, 1987
Clinoptilolite, USA	Aerobic manure decomposition	60	1.8	Witter and Kirchmann, 1989
Teage Mineral Products	NH_3	Dry	6.255 - 14.155	Bernal and Lopez-Real, 1993a
Teage Mineral Products	Pig slurry	Dry	0.74 to 2.40	Bernal et al., 1993b
Clinoptilolite, Chifeng, China	NH_3	20 - 60	0.097 – 0.13	Li et al., 2010
Natural zeolite	Poultry manure	0 - 10	1.4 ± 0.18 and 2.38 ± 0.15	This paper, 2013

2.5 Conclusion

There is a significant potential for the zeolite as an adsorbent material for NH_3 removal from air stream in poultry operations. Moisture level (0%, 5%, or 10%) did not affect NH_3 removal efficiency of the tested zeolite particles (-14+40 or -8+40). Zeolite with the two particle size had similar NH_3 removal efficiency while zeolite with larger particle size (-8+40) would be preferred as filter adsorbent material due to lower air flow resistance. Retention time is a significant ($p<0.01$) factor that influences NH_3 adsorption. Higher NH_3 adsorption rate can be expected with a higher retention time. As retention time increases from 0.73 to 1.29, NH_3 adsorption capacity at breakthrough point increases from 1.40 ± 0.18 to 2.38 ± 0.15 mg/g NH_3/zeolite.

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Chapter 3

EFFECTS OF MOISTURE CONTENT AND LITTER AMENDMENT APPLICATION RATE ON AMMONIA EMISSION FROM BROILER LITTER

3.1 Introduction

NH_3 is an important atmospheric pollutant due to its impact on ecosystems. Major impacts associated with atmospheric NH_3 and its deposition includes eutrophication, soil acidification, and aerosol formation both in national and regional. The health effects of NH_3 are well known. NH_3 can be rapidly absorbed in the upper airway of human respiratory system (Nahm, 2005). Also, NH_3 is an odorant with irritant properties. NH_3 is one of the criteria air pollutants (CAPs) defined by the Environmental Protection Agency (USEPA, 2013). Air quality associated with animal feed operations (AFOs) continues to be a high-priority issue for the animal agriculture in the U.S. According to the most recent estimates, the total NH_3 emission in the US is 4.36 million ton and 86.3% of the NH_3 emissions are coming from agriculture source (USEPA, 2008). Among the NH_3 emission from agricultural sector, 56.20% is from AFOs, which is impacts environment but also impact the live production performance, animal health, and welfare. Within the last 5 years, 2008-2012, emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) have decreased the most, while particulate matter (PM) and NH_3 show the least change (USEPA, 2013).

Several methods have been studied and used in NH_3 emissions mitigation: 1) using new or alternative bedding materials for each broiler operation during each grow-out, 2) controlling and lowering litter moisture content, decrease bacteria activity and decrease NH_3 generation; 3) applying chemical additives that decrease manure pH, shift the equilibrium in favor of ammonium (NH_4^+) over NH_3, and bind NH_3, adsorbent additives that adsorb NH_3 on adsorbent; 4) Filtration using zeolite, active charcoal, bio-filters, scrubbers to treat exhaust air and remove NH_3 (Lau and Cheng, 2007). Gates et al. (2008) found using new bedding material decreased NH_3 emission by 27 – 47% compared with built-up litter. Another bedding material, 40 – 60% peat with straw mixture, was found decrease 57% NH_3 emission (Jeppsson, 1999). A lab scale study was conducted with compost medium and activated carbon as an added material, and NH_3 concentration reduced more than 95% (Liang et al., 2000). Another woodchips medium biofilter was reported to reduce NH_3 volatilization from 54 to 93% (Sheridan et al., 2002). Lahav et al. (2008) reported an acidic ($0<pH<5$) bubble column reactor, which can reduce 100% NH_3 emission. Vegetative environmental buffer was investigated by Adrizal et al. (2008) to capture NH_3 and decrease NH_3 emission and 78% NH_3 emission reduction was found downwind (Ndegwa et al., 2008; Patterson et al., 2008). Among all the methods, acidic litter additives are the most wildly used in poultry house. Acidifying and adsorbent have been proved potential exists to develop further practical and cost-effective additives (McCrory and Hobbs, 2001).

Reduction of NH_3 volatilization has been shown to be possible, particularly with acidifying and adsorbent additives, and potential exists to develop further practical and cost-effective additives in this area (McCrory and Hobbs, 2001). However, the performance of clinoptilolite has been mixed. Nakaue et al. (1981) reported modest reductions in NH_3 levels in the poultry house, while Amon et al. (1997) reported large increases in NH_3 levels when clinoptilolite was applied to litter. Litter moisture content had also been investigated to have influence on NH_3 emissions (Cabrera and Chiang, 1994; Liu et al., 2007; Miles et al., 2011). NH_3 emissions were found increasing as moisture content increase at low moisture level (Moisture content < 30% to 50%) and decreasing at high moisture level.

Additives are wildly used in poultry house recently. But with only one time application at the beginning of a flock, high NH_3 emission had found after 3 to 4 weeks of an application (Miles et al., 2008). To improve litter amendment effectiveness, frequent litter amendment application during grow-out period was investigate. The objective of this study was to compare different litter amendments (PLT™, zeolite, and active charcoal) at different moisture levels (20%, 30%, and 40%) and different application rates in reducing NH_3 emission from poultry litter.

3.2 Methods and Material

3.2.1 Litter Amendments

Three different litter amendments were tested in this study: PLT (Jones-Hamilton Co., Walbridge, Ohio), zeolite (Bear River Zeolite, CO., INC., Preston, ID), and active charcoal (AquaCarb® 1230AWC, Siemens, USA). All these three amendments are commercial available and their properties are shown in Table 3.1.

Table 3.1: Amendments properties

Common name	PLT™	Zeolite	Activated charcoal
Chemical formula	93% $NaHSO_4$	$(Na, K, Ca)_{2\text{-}3}Al_3(Al, Si)_2Si_{13}O{\cdot}12H_2O$	C
Form	Granules	Granules	Granules
Color	White	Green	Black
pH	1.5 – 2.0	6.0 – 8.0	6.5 – 8.0
NH_3 reduction potential	13.3%	1.8 – 2.1%	----

3.2.2 Litter Samples

Raw litter sample was collected from a commercial broiler farm in Delaware. The litter was stored in sealed plastic bags that were kept in a cold room at 4°C. The initial moisture content (MC) of the litter ranged from 15% to 25%.

For each trial, 0 to 8 kg of raw litter was oven-dried to achieve 20% MC and divided into three group samples. The dried sample was air cooled for 24 hr to room temperature, 22 ^oC. Then 0.5 kg litter sample with 20% MC was collected for nutrients analysis including TKN, NH_3-N, and pH. Distilled water was added into two group samples that homogenized to receive 30 and 40 % MC. Each group sample was further divided into four equal amount subsamples for four different application rates, 0, 0.1, 0.2 and 0.4 US dollar per m^2. The application rates were determined based on the price of the materials. Therefore, there were twelve litter samples with three MCs and four application rates tested in each trial (Table 2.2). Each litter sample was placed in one 1-gal bucket with a 0.03 m^2 (0.32 ft^2) surface area and 10 cm (4 in) depth. Only one litter amendment with the four rates was examined during one trial and applied to the top layers (1.3 cm) of litter samples. The surface layer (1.3 cm) litter in each bucket was taken and mixed with the amendment to mimic the bird activities. Then the treated litter was added back the bucket and 13.8-kpa (2-psi) pressure was applied to the bucket for one minute to simulate the compaction in the field under commercial condition.

Table 3.2: Amendment application rate

Cost, $\$/m^2$	PLT rate, g/m^2	Zeolite rate, g/m^2	Charcoal rate, g/m^2
0 (Control)	0	0	0
0.1 (Low)	183	732	366
0.2 (Mid)	366	1465	732
0.4 (High)	732	2929	1465

3.2.3 Emission Vessel System

The twelve buckets were set in each trial in the EV, and eight trials (three PLT, two zeolite, two charcoal) have be done to test their performance in NH_3 emission reduction.

A twelve-emission vessels (EV) system was used to collect the NH_3 emission rates from the litter samples (Figure 1). Each 1-gal buckets of each trial was placed in one EV and 3 LPM constant fresh air was provided. Exhaust air from each vessel was sequentially directed into a sampling manifold through 3-way solenoid valves (type 6014, Christian Bürkert GmbH & Co. KG, Christian-Bürkert-Straße, Ingelfingen, Germany) with ten min intervals, first nine min for stabilization and last one min for measurement; the average of outputs over the 60s intervals was recorded. This sampling sequence yielded a measurement cycle of 130 min for the entire system (including 10 min for the ambient air). A photoacoustic multi-gas analyzer (model 1412, INNOVA AirTech Instruments A/S, Ballerup, Denmark) was used to measure NH_3 and CO_2 concentrations and dew point. The outputs from the multi-gas analyzer were logged at 1 s intervals into a PC through serial communication port with a Lab VIEW program (Version 2009, National Instrument, Austin, Texas). A relay module (EBR-24, Measurement Computing Corporation, Norton, Mass.) was driven by the LabVIEW program to control the solenoid valves (Figure 3.1). Two temperature probes (TMC6-HD, Onset, Bourne, MA) with data logger (U12-006 4 External Channel USB Logger, Onset, Bourne, MA) were placed in the surface layer (2.5 cm depth) and middle (5cm depth) of each litter sample to measure the temperature change of the litter during the experiment. The EV system was located in an environmental controlled lab with constant temperature, 20 ^{o}C. One amendment was tested for a trial. Duplicate trials were finished for zeolite and charcoal over a 2-wk period per trial, and triplicate trials were conducted for PLT through a 4-wk period per trial.

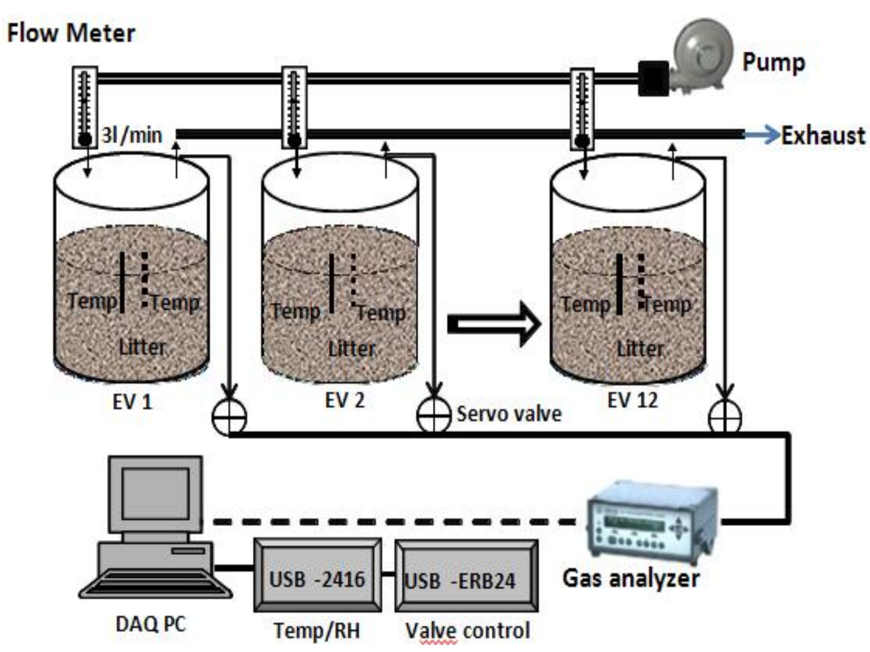


Figure 3.1: Sequence emission vessel system

3.2.4 Data Analysis

NH_3 daily emission rate (ER) was calculated as mass of NH_3emitted from an EV.

$$ER = m \times VR \times (C_e - C_i) \times \frac{17.03 g/mol}{22.4 L/mol} \quad (6)$$

where,

m is a conversion factor from g/min to mg/d, 1.44,

ER is daily emission rate, mg/d,

VR is ventilation rate, L/min,

C_e is daily average exhaust NH_3 concentration, ppm, and

C_i is daily average inlet NH_3 concentration, ppm.

NH_3 cumulative emissions (CE) were calculated by daily ER.

$$\mathrm{CE_i} = \sum_{i=1}^{n} \mathrm{ER_i} \quad (7)$$

where,

CE_i is cumulative emission by day n, mg, and

n is storage time, d.

Reduction rate of daily emission (RR_d) and cumulative emission (RR_c)

$$\mathrm{RR_d} = \frac{\mathrm{ER_{i,control}} - \mathrm{ER_{i,treatment}}}{\mathrm{ER_{i,control}}} \times 100\% \quad (8)$$

$$\mathrm{RR_c} = \frac{\mathrm{CE_{i,control}} - \mathrm{CE_{i,treatment}}}{\mathrm{CE_{i,control}}} \times 100 \quad (9)$$

where,

$ER_{i,\ control}$ is daily emission rate of litter without litter amendment,

$ER_{i,\ treatment}$ is daily emission rate of litter with litter amendment,

$CE_{i,\ control}$ is cumulative emission without litter amendment, and

$CE_{i,\ treatment}$ is cumulative emission with litter amendment.

3.2.5 Statistical Method

Procedures of JMP Pro 10 (SAS Institute, Inc., 2013) were used in the following analyzing. Daily emission rates and emission reduction rates of litter treated by each amendment with different application rates were compared by Tukey HSD test (Tukey-Kramer test). Each Pair, Student's t-tests were used to compare the emission reduction rate in within each moisture levels.

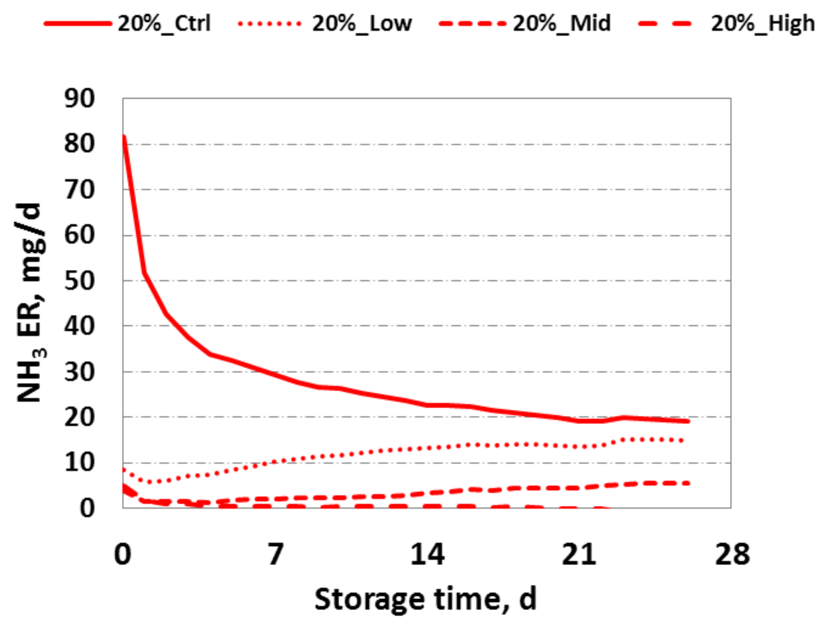
3.3 Results and Discussion

3.3.1 Effect of PLT on NH_3 Emission at 20% MC

Daily NH_3 ER of control litter sharply decreases from 80 to 40 mg/d during the first three days while ERs of PLT treated litters remained steady and were significantly lower (Figure 3.2(a) and Table 3.3). During the first 13 days of application NH_3 ER from treated litter samples was still significantly lower than that of control (p-value < 0.05). By the 14-d, there was no significant difference between NH_3 ERs of low rate and control (p-value > 0.05). In contrast, ERs of mid and high rates were significantly lower than those of the control during the 4-wk period

NH_3 emission reduction rate (ERR) is shown in Figure 3.2(b) and Table 3.4. A higher ERR was observed from mid (94%) and high (98%) PLT application rate compared with low (70%) application rate after one week from application. The different performance between mid and high application rate lasted for the first three weeks. In general, a higher NH_3 ERR can be obtained from higher PLT application rate and the performance of NH_3 mitigation by PLT diminished by the time.

Cumulative NH_3 emission reduction of low, mid, and high PLT treatments during the 4-week period were 507.2±115.2 mg, 742.9±53.6 mg, and 840.2±2.26 mg, respectively (Figure 3.2(c) and (d)). Cumulative emission reduction rates were 61%, 90%, and 100%, respectively.



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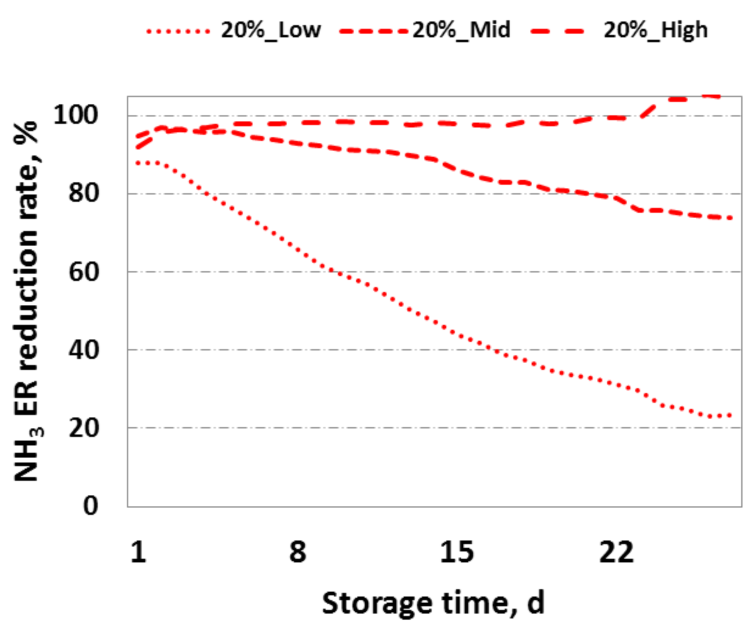
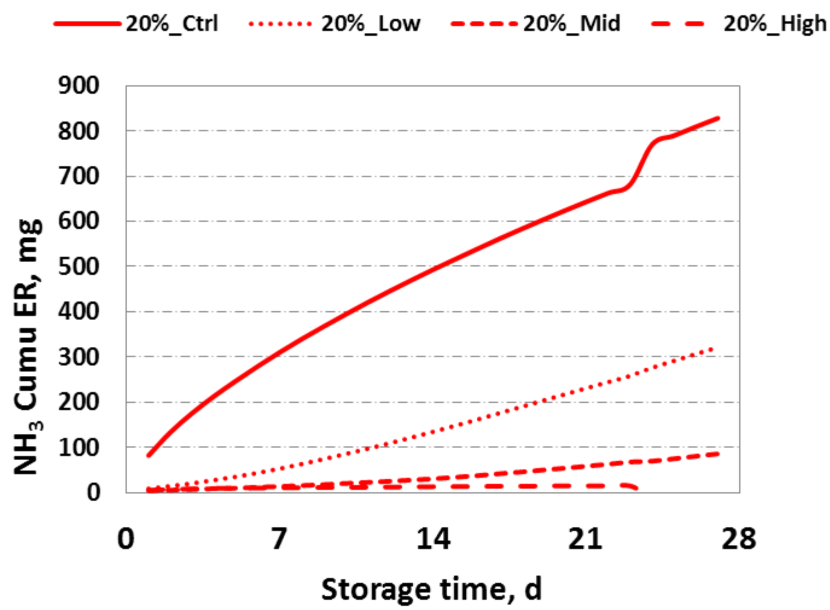


(b)

Figure 3.2: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 20% MC at four different PLT application rates, 0(control), 183 (low), 366 (mid) and 732 (high) g/m.

Figure 3.2 Continued



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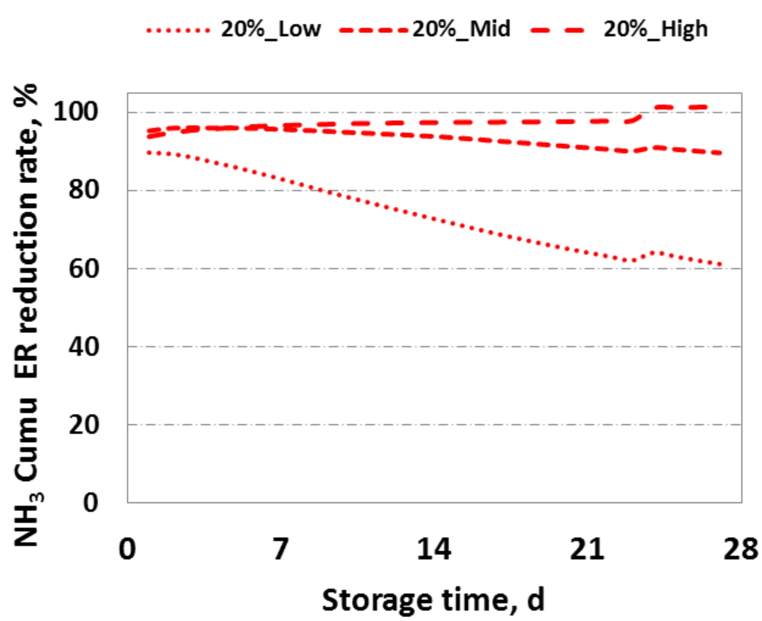


(d)

Table 3.3: NH_3 emissions from EVs with PLT treatment in four different application rates, 0(Ctrl), 183(Low), 366(Mid), and 732 g/m^2 (High) at 20% moisture level (n=3)

ER(mg/d)	Mean(S.E.)			
Age(day)	Ctrl	Low	Mid	High
1	81.7^{A}(16.3)	8.4^{B}(2.7)	3.8^{B}(0.7)	5.1^{B}(2.6)
7	30.8^{A}(4.1)	9.4^{B}(3.2)	1.9^{B}(1.1)	0.5^{B}(0.9)
14	23.5^{A}(3.4)	12.9^{A,B}(4.0)	2.8^{B,C}(1.4)	0.3^{C}(0.9)
21	19.9^{A}(2.7)	13.7^{A,B}(3.5)	4.4^{B,C}(2.1)	0.0^{C}(0.9)
27	19.2^{A}(2.3)	14.8^{A}(2.7)	5.4^{A,B}(2.5)	1.0^{B}(0.5)

Table 3.4: NH_3 emissions reduction from EVs with PLT treatment in three different application rates compare with control, 0(Ctrl), 183(Low), 366(Mid), and 732 g/m^2 (High) at 20% moisture level (n=3)

ERR(%)	Mean(S.E.)		
Age(day)	Low	Mid	High
1	0.88^{A}(0.06)	0.95^{A}(0.02)	0.92^{A}(0.05)
7	0.70^{B}(0.10)	0.94^{A}(0.04)	0.98^{A}(0.03)
14	0.47^{B}(0.10)	0.89^{A}(0.05)	0.98^{A}(0.04)
21	0.33^{C}(0.07)	0.80^{B}(0.07)	0.99^{A}(0.05)
27	0.23^{C,D}(0.05)	0.74^{B}(0.10)	1.05^{A}(0.02)

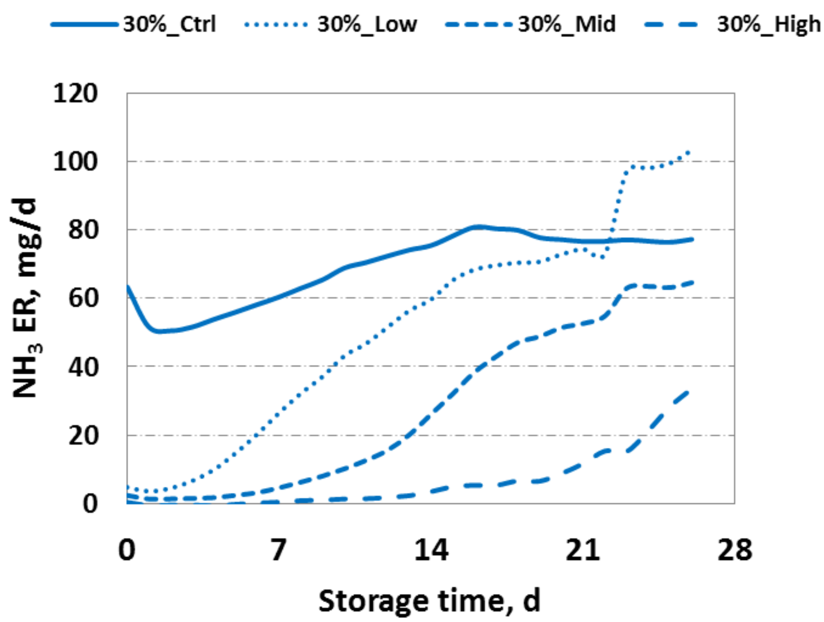
Note: NH_3 emissions reductions were compared by each single day within 20% moisture level, different superscript letter in that day means significant different ($P<0.05$)

NH_3 emission and emission reduction at 30% moisture level are shown in Figure 3.3, Table 3.5, and Table 3.6. NH_3 ERs of control with 30% MC were relatively stable during the 4-week period. NH_3 ERs of PLT treated litter samples were significantly lower than those of control litter during the first week. NH_3 ERs of treated litter samples gradually increased with the storage time. There were significant differences between treated litter samples and control after 14, 21, and 27 days of application for low, mid, and high rate, respectively (p-value > 0.05).

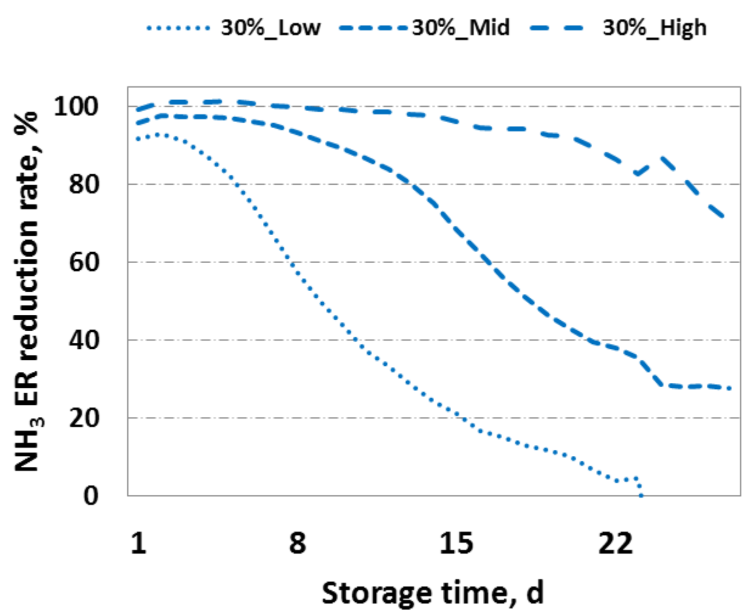
NH_3 ERRs are shown in Figure 3.3(b) and Table 3.6. After one week of application a significant ($p<0.05$) difference was shown between low and the other two PLT application rates. NH_3 ERR from mid and high PLT application rates were significantly ($p<0.05$) higher than those from low rate sample at the end of second week. NH_3 ERR of high rate was significantly higher than mid-rate till 21 days after application.

Cumulative NH_3 emission reduction of low, mid, and high PLT treatments during the 4-week period were 218.6±544.3 mg, 1114.9±405.9 mg, and 1731.8±108.5 mg, respectively (Figure

3.2 (c) and (d)). Cumulative emission reduction rates were 12%, 61%, and 94%, respectively. Higher PLT application rate achieved higher NH_3 ERR and its efficiency lasted longer at 30% moisture level. Compared to 20% MC, NH_3 ERRs of three rates were lower at 30% MC.



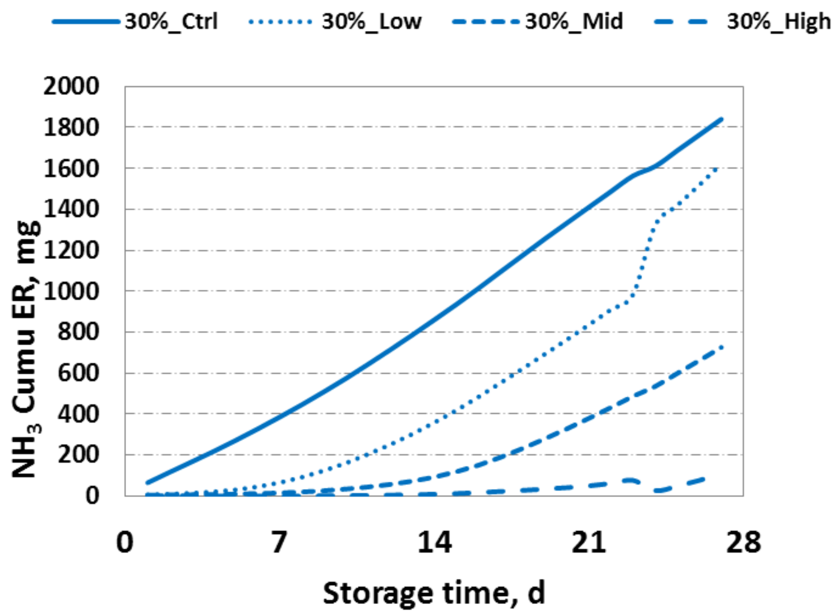
(a)



(b)

Figure 3.3: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 30% MC at four different PLT application rates, 0(control), 183 (low), 366 (mid) and 732 (high) g m^{-2}.

Figure 3.3 Continued



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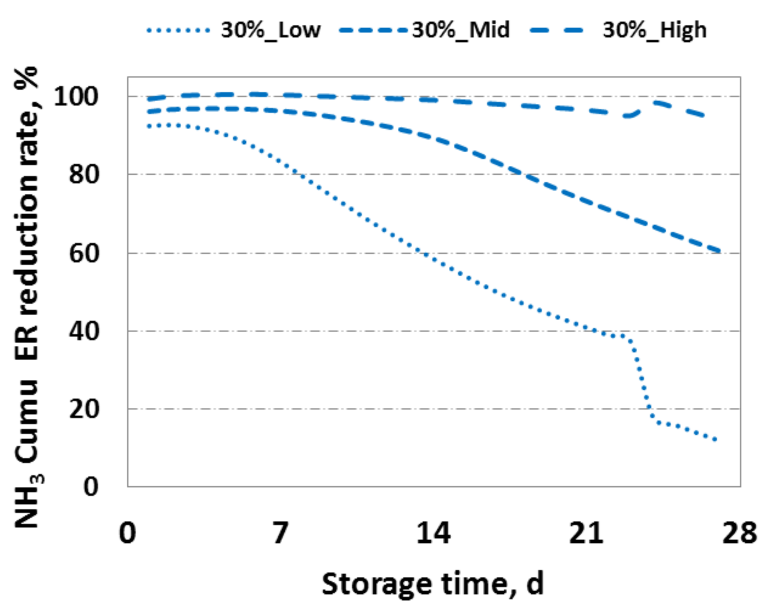


(d)

Table 3.5: NH_3 emissions from EVs with PLT treatment in four different application rates, 0(Ctrl), 183(Low), 366(Mid), and 732 g/m^2 (High) at 30% moisture levels (n=3)

ER(mg/d)	Mean(S.E.)			
Age(day)	Ctrl	Low	Mid	High
1	63.4^{A}(14.3)	4.7^{B}(0.9)	2.4^{B}(0.7)	0.4^{B}(0.2)
7	58.2^{A}(6.1)	20.3^{B}(6.6)	3.2^{B}(2.1)	0.1^{B}(0.8)
14	74.2^{A}(9.7)	56.4^{A,B}(22.6)	20.1^{A,B}(7.9)	2.3^{B}(2.9)
21	77.2^{A}(17.5)	72.9^{A}(31.3)	51.4^{A}(22.9)	8.8^{A}(6.6)
27	77.3(28.2)	103.4(33.2)	64.6(36.3)	33.5(28.0)

Table 3.6: NH_3 emissions reduction from EVs with PLT treatment in three different application rates compare with control, 0(Ctrl), 183(Low), 366(Mid), and 732 g/m^2 (High) at 30% moisture level (n=3)

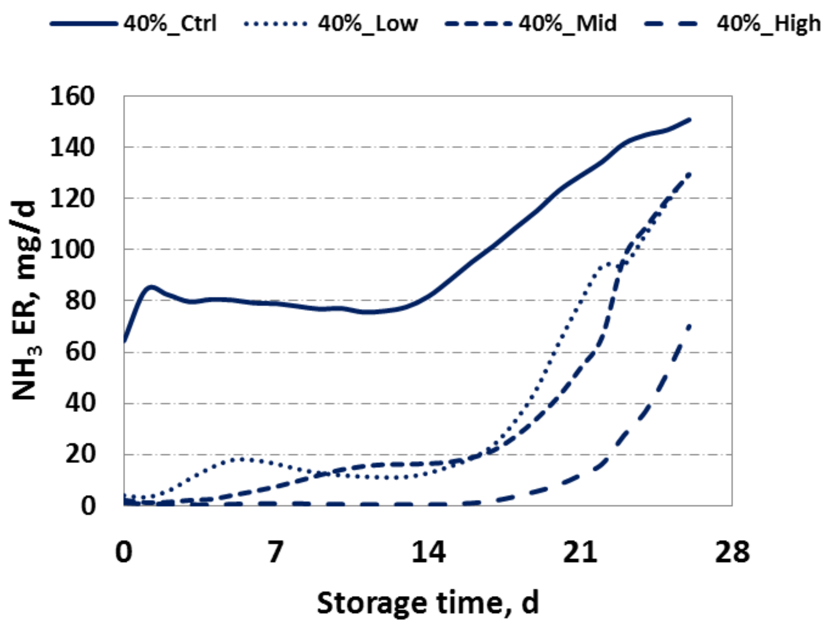
ERR(%)	Mean(S.E.)		
Age(day)	Low	Mid	High
1	0.92^{A}(0.03)	0.96^{A}(0.02)	0.99^{A}(0.00)
7	0.66^{B}(0.09)	0.95^{A}(0.03)	1.00^{A}(0.01)
14	0.24^{B,C}(0.25)	0.75^{A}(0.09)	0.97^{A}(0.04)
21	0.07^{B}(0.28)	0.40^{A,B}(0.14)	0.89^{A}(0.09)
27	0.38^{A,B}(0.07)	0.28^{A,B}(0.21)	0.71^{A}(0.25)

Note: NH_3 emissions reductions were compared by each single day within 30% moisture, different superscript letter in that day means significant different (P<0.05)

NH_3 emission and emission reduction at 40% moisture level are shown in Figure 3.4 and Tables 3.7 and 3.8). NH_3 ERs of control with 40% MC were relatively stable during the first 2-week period and increased after 2-week of application. NH_3 ERs of treated litter were less than 20 mg d^{-1}until the 17th, 18th, and 23rd day of the storage period. After 21 days of PLT application, NH_3 ER of low and mid rates were not significantly lower than those of control ($p<0.05$).

NH_3 ERR is shown in Figure 3.4(b) and Table 3.8. There was significant difference between low and high rate after one week of PLT application. High rate sample demonstrated a significantly higher ERR compared to low rate. Similar result was observed during the second and third weeks. After four weeks application, the NH_3 ERR of high-rate , 63%, was found higher than the ERRs of mid-rate,17% and low-rate, 13%.

Cumulative NH_3 emission reduction of low, mid, and high PLT treatments during the 4-week period were 1902.1±377.14 mg (67%), 1809.9±282.3 mg (64%), and 2554.3±226.94 mg (90%), respectively (Figure 3.2 (c) and (d)). Cumulative emission reduction rates were 67%, 64%, and 90%, respectively. Similar as treatment at 20% and 30% MC, higher PLT application rate achieved higher NH_3 ERR and its efficiency lasted longer at 40% moisture level.



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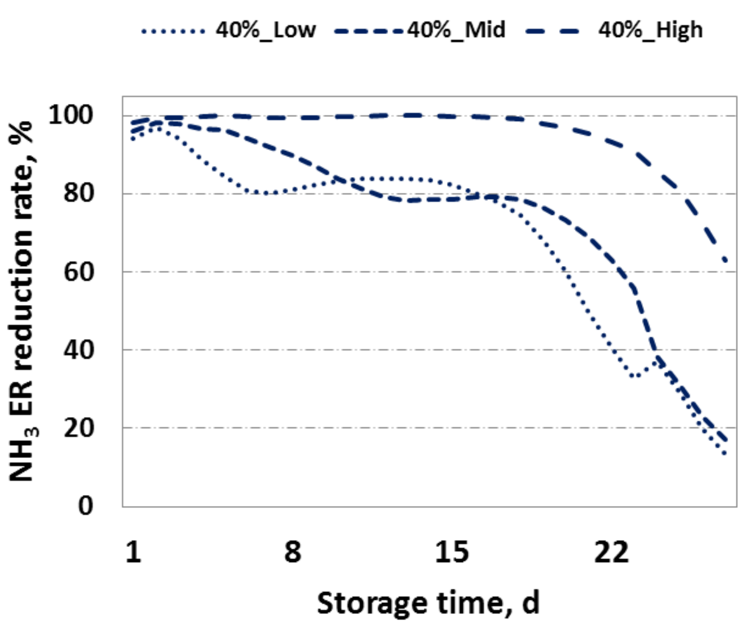
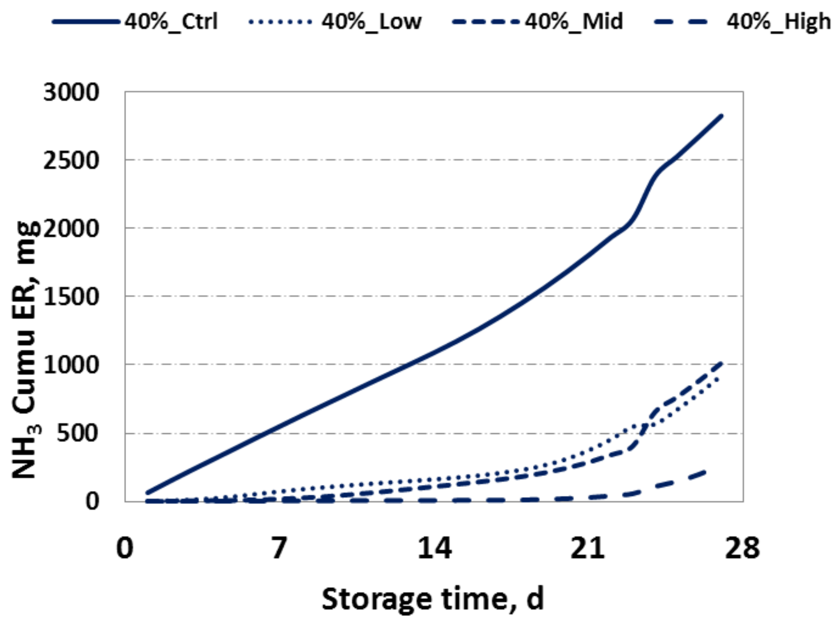


(b)

Figure 3.4: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 40% MC at four different PLT application rates, 0(control), 183 (low), 366 (mid) and 732 (high) g m^{-2}.

Figure 3.4 Continued



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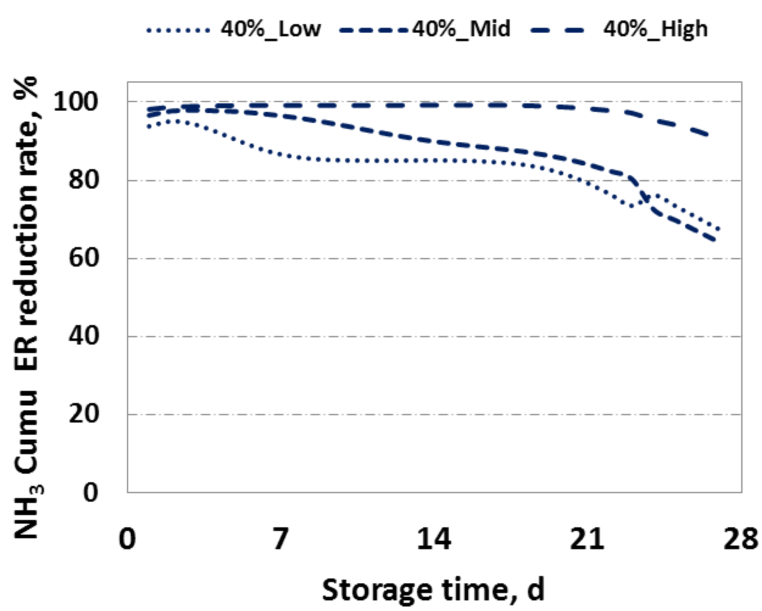


(d)

Table 3.7: NH_3 emissions from EVs with PLT treatment in four different application rates, 0(Ctrl), 183(Low), 366(Mid), and 732 g/m^2 (High) at 40% moisture levels (n=3)

ER(mg/d)	Mean(S.E.)			
Age(day)	Ctrl	Low	Mid	High
1	64.4^{A}(19)	4.0^{B}(2.1)	2.2^{B}(0.7)	1.2^{B}(0.7)
7	79.2^{A}(13.5)	17.8^{B}(9.0)	5.6^{B}(2.1)	0.8^{B}(1.3)
14	77.7^{A}(24.7)	11.2^{B}(3.1)	16.2^{B}(8.3)	0.4^{B}(0.9)
21	123.1^{A}(31.5)	$63.5^{A,B}$(20.7)	$42.7^{A,B}$(25.0)	8.1^{B}(7.7)
27	150.8^{A}(35.6)	130.0^{A}(28.6)	129.4^{A}(42.7)	70.1^{A}(53.7)

Table 3.8: NH_3 emissions reduction from EVs with PLT treatment in three different application rates compare with control, 0(Ctrl), 183(Low), 366(Mid), and 732 g/m^2 (High) at 40% moisture level (n=3)

ERR(%)	Mean(S.E.)		
Age(day)	Low	Mid	High
1	0.94^{A}(0.02)	0.96^{A}(0.02)	0.98^{A}(0.01)
7	0.80^{B}(0.11)	$0.92^{A,B}$(0.04)	0.99^{A}(0.01)
14	0.84^{A}(0.05)	0.79^{A}(0.13)	1.00^{A}(0.01)
21	0.50^{B}(0.13)	$0.69^{A,B}$(0.12)	0.96^{A}(0.04)
27	0.13(0.02)	0.17(0.09)	0.63(0.27)

Note: NH_3 emissions reductions were compared by each single day within 40% moisture, different superscript letter in that day means significant different ($P<0.05$)

PLT applications can reduce more than 90% of the NH_3 emission on the first day for all the moisture levels and application rates. For 20% moisture level, the reduction effectiveness of the three rates on NH_3 emission were significant until day 5 for low rate, day 7 for mid-rate, and day 12 for high rate, respectively. For 30% moisture level, the three rates were effective till day 9 for low rate, day 14 for mid-rate, and day 19 for high rate, respectively($p<0.05$). For 40% moisture level, longevity of three application rates extended to day 19 for low rate, day 20 for mid-rate, day 24 for high rate ($p<0.05$) (Appendix A).

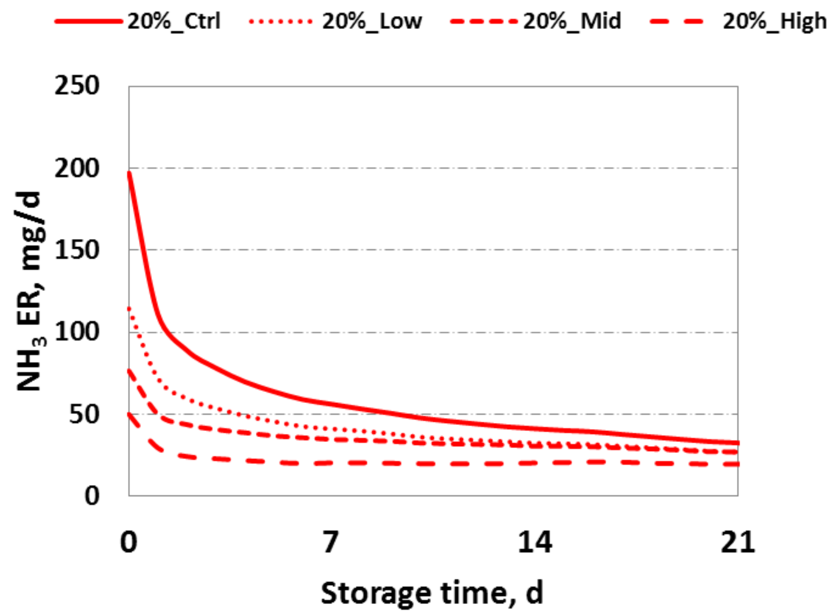
On the other hand, litter moisture content had a positive influence on NH_3 ER. NH_3 cumulative emission of control during four-week period from 20%, 30%, and 40% MC increased from 828.5 mg to 1840.1 mg and 2823.4 mg, respectively. For low rate (183 g/m), NH_3 emission reduction rates under different litter MCs ranked as: 40% > 20% > 30% MC.

For mid-rate (366 g/m), litter with 20% and 30% MC emitted less NH_3 while more PLT application did not significantly improve the emission reduction. As the application rate increased to high (732 g/m^2), cumulative emission reduction rate at three MCs were more than 95% after three weeks of application.

3.3.2 Effect of Zeolite on NH_3 Emission

Figure 5(a) and Table 3.9 show that at 20% MC NH_3 ERs of high and mid zeolite application rates on the application day were significantly lower than from control litter(p-value < 0.05), but NH_3 ER of low rate was not significantly lower than control (p-value > 0.05). After one week of application NH_3 ERs of high and mid zeolite application rates were still lower than control emission, but only high rate was significantly lower (p-value > 0.05). After two weeks of zeolite application all three rates showed no significantly different in NH_3 ER compared with control.

NH_3 ERR is shown in Figure 3.5(b) and Table 3.10. After one week from the initial application significant higher NH_3 ERR occurred between high and the other two rates. After three weeks of application, NH_3 ERR with low and mid rates was found no significantly different than control (p-value < 0.05), but higher NH_3 ERR was obtained with high rate. Cumulative NH_3 emission reduction during the three-week experimental period with low, mid, and high rates were 375.5±74.8 mg, 524.2±85.65 mg, and 823.32±78.45 mg, respectively (Figure 3.5 (c) and (d)). Cumulative emission reduction rates were 28%, 39%, and 62%, respectively.



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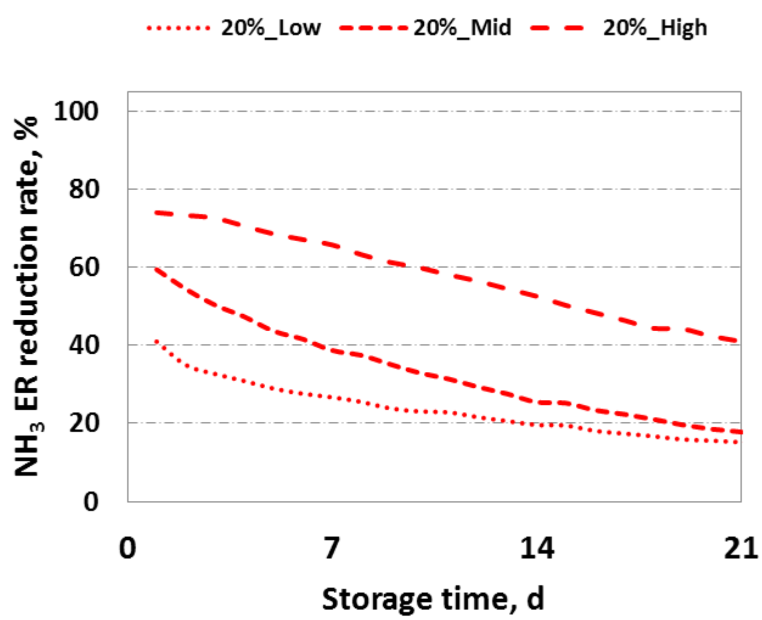
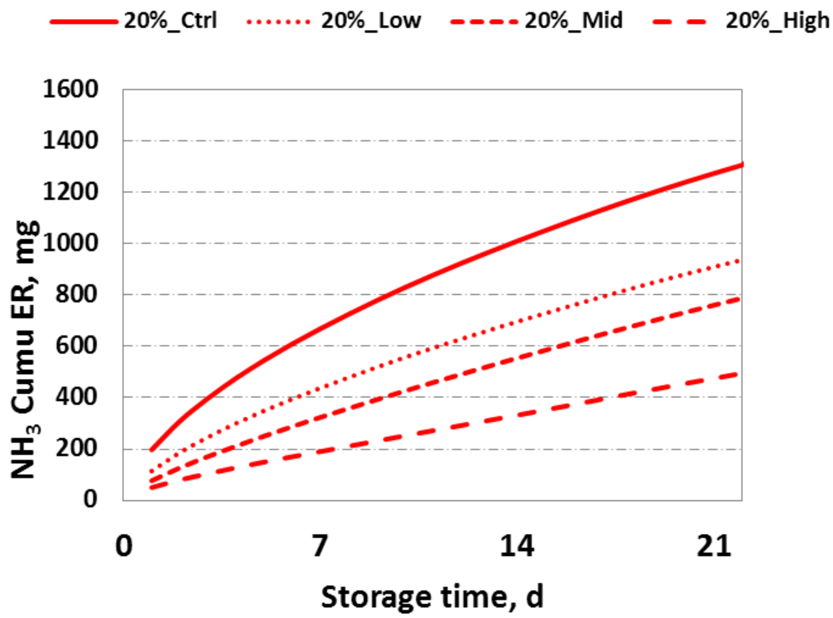


(b)

Figure 3.5: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 20% MC at four different zeolite application rates, 0(control), 366 (low), 732 (mid) and 1465 (high) g/m.

Figure 3.5 Continued



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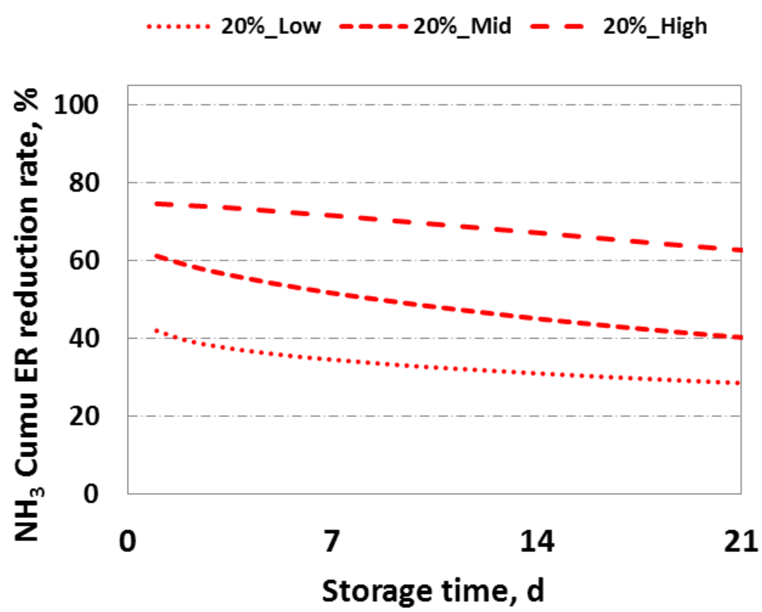


(d)

Table 3.9: NH_3 emissions from EVs with Zeolite treatment in four different application rates, 0(Ctrl), 366(Low), 732(Mid), and 1465 g/m (High) at 20% moisture levels (n=2)

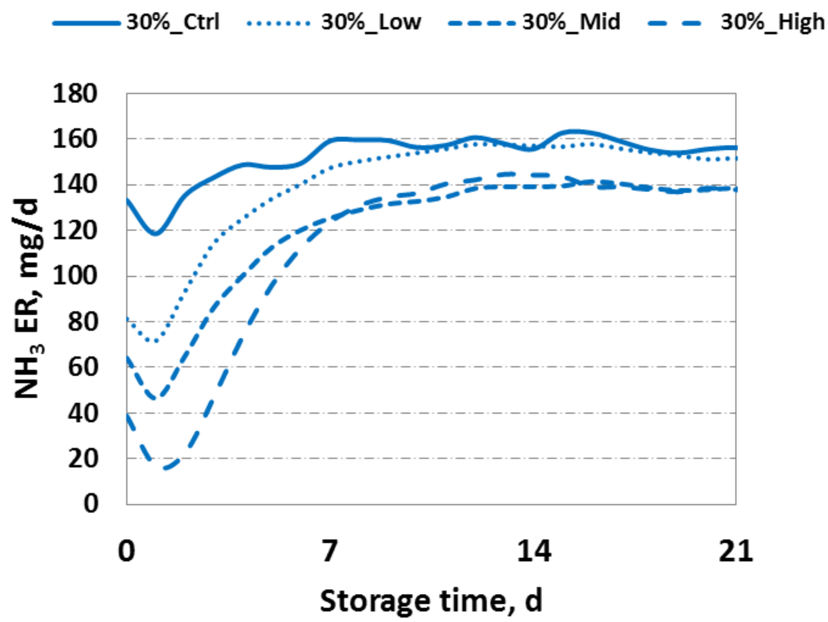
Zeolite	Mean(S.E.)			
Age(day)	Ctrl	Low	Mid	High
1	197.2^{A}(35.3)	$114.4^{A,B}$(9.5)	76.5^{B}(5.0)	50.1^{B}(3.1)
7	59.0^{A}(9.4)	$42.6^{A,B}$(2.9)	$35.9^{A,B}$(3.9)	20.1^{B}(2.3)
14	42.6^{A}(8.1)	33.4^{A}(2.4)	31.5^{A}(5.0)	20.1^{A}(3.4)
21	33.5(6.2)	27.7(1.5)	27.4(4.4)	19.7(3.5)
23	32.1(6.0)	26.2(1.9)	26.5(4.0)	19.7(3.8)

Table 3.10: NH_3 emissions reduction rate from EVs with Zeolite treatment in three different application rates 366 (Low), 732(Mid), and 1465 g/m (High) at 20% moisture levels (n=2)

Zeolite(ERR)	Mean(S.E.)		
Age(day)	Low	Mid	High
1	0.41^{B}(0.06)	$0.59^{A,B}$(0.10)	0.74^{A}(0.03)
7	0.27^{B}(0.07)	0.39^{B}(0.03)	0.66^{A}(0.02)
14	0.20^{B}(0.10)	0.25^{B}(0.02)	0.53^{A}(0.01)
21	0.15(0.11)	0.18(0.02)	0.41^{A}(0.00)
23	0.16(0.10)	0.17(0.03)	0.39(0.01)

Note: NH_3 emissions were compared by each single day within 20% moisture, different superscript letter in that day means significant different ($P<0.05$)

NH_3 ER and ERR at 30% moisture levels is shown in Figure 3.6 and Tables 3.11 and 3.12. During the first week of the storage, three application rates had lower NH_3 ERs than control NH_3 ERR of high rate was significantly higher than mid and low rates (p-value < 0.05). Both low and mid rates had lower ERs than control (p-value < 0.05), but there was no significant difference between the two rates during the first week. After one week of application no difference was in NH_3 ERs among the three rates and control (p-value > 0.05).. Cumulative NH_3 emission reduction during the three-week period at low, mid, and high rates were 279.8 mg, 726.4 mg , and 887.5 mg, respectively (Figure 3.6 (c) and (d)). Cumulative emission reduction rates were 8%, 21%, and 25%, respectively.



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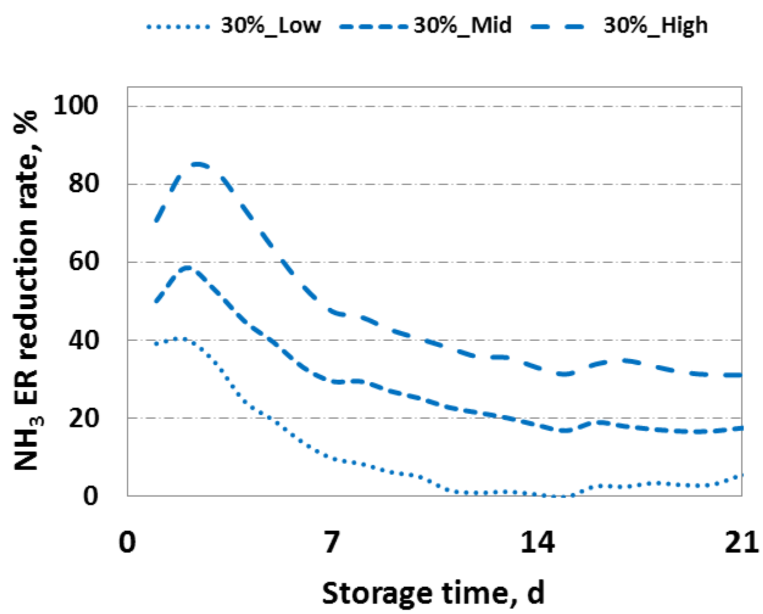
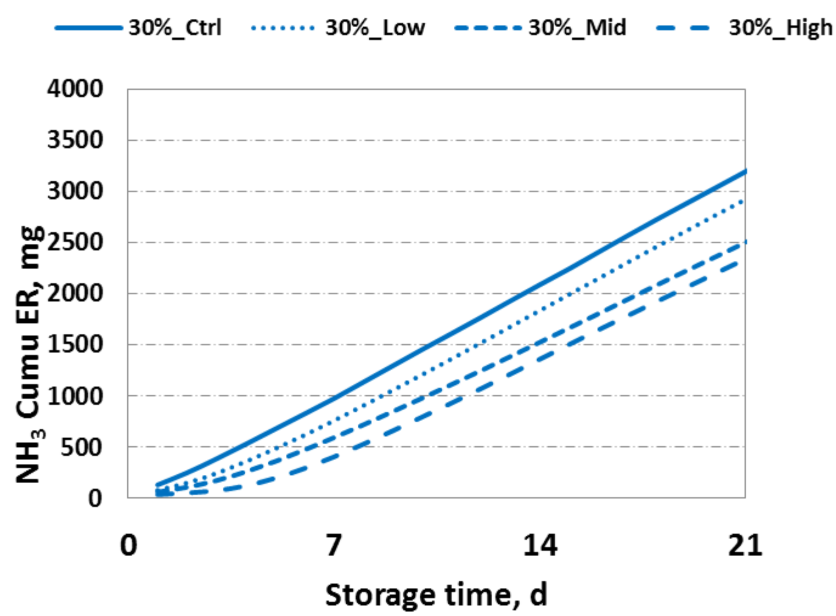


(b)

Figure 3.6: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 30% MC at four different zeolite application rates, 0(control), 366 (low), 732 (mid) and 1465 (high) g/m.

Figure 3.6 Continued



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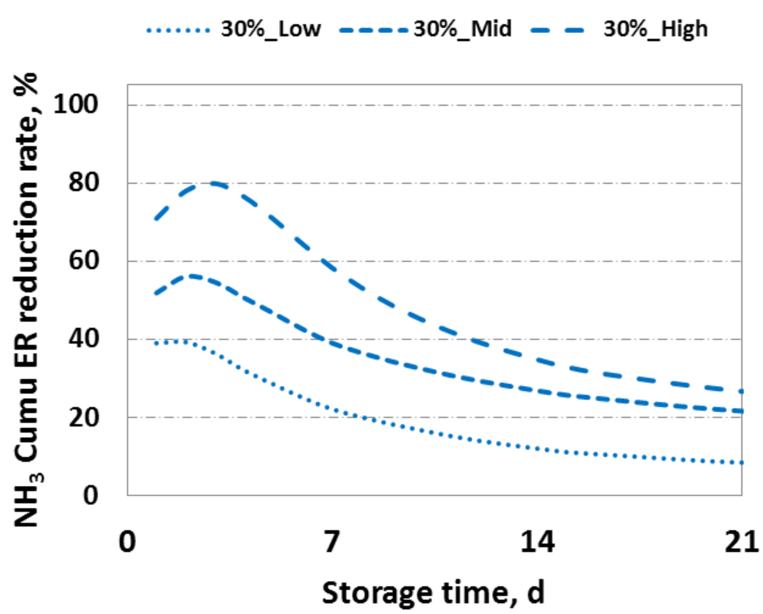


(d)

Table 3.11: NH_3 emissions from EVs with Zeolite treatment in four different application rates, 0(Ctrl), 366(Low), 732(Mid), and 1465 g/m (High) at 30% moisture levels (n=2)

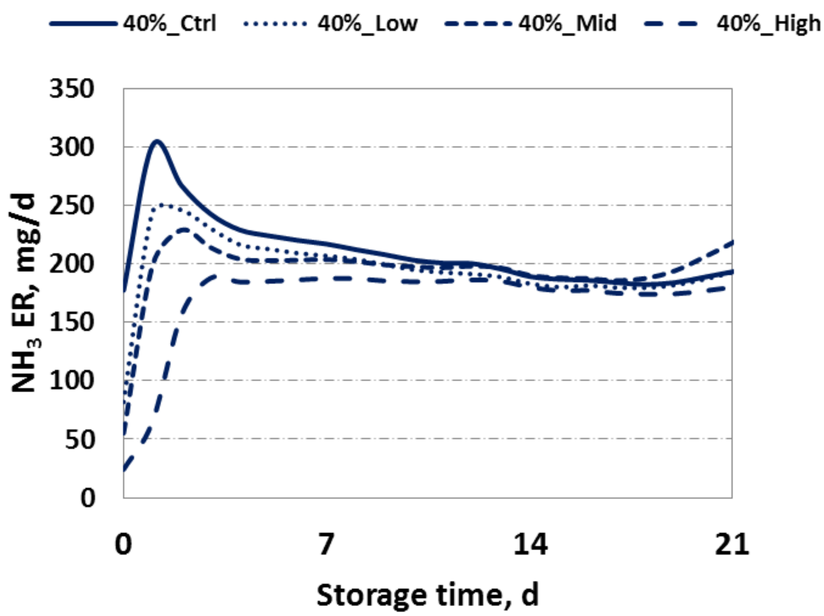
Zeolite	Mean(S.E.)			
Age(day)	Ctrl	Low	Mid	High
1	133.3^{A}(34.4)	81.3^{A}(21.7)	64.2^{A}(8.1)	38.8^{A}(9.3)
7	149.4(98.7)	140.3(97.4)	120.2(92.1)	112.3(103.1)
14	158.1(101.6)	157.5(101.5)	139.2(98.7)	144.6(128.4)
21	155.6(99.1)	151.2(100.1)	137.9(96.7)	138.6(117.5)
23	153.9(99.8)	150.7(104.1)	137.2(99.0)	137.8(116.3)

Table 3.12: NH_3 emissions reduction rate from EVs with Zeolite treatment in three different application rates 366 (Low), 732(Mid), and 1465 g/m (High) at 30% moisture levels (n=2)

Zeolite(ERR)	Mean(S.E.)		
Age(day)	Low	Mid	High
1	0.39^{B}(0.01)	0.50^{B}(0.07)	0.71^{A}(0.01)
7	0.10(0.06)	0.30(0.15)	0.47(0.34)
14	0.01(0.00)	0.18(0.01)	0.33(0.38)
21	0.05(0.04)	0.18(0.10)	0.31(0.32)
23	0.07(0.07)	0.18(0.11)	0.30(0.30)

Note: NH_3 emissions were compared by each single day within 30% moisture, different superscript letter in that day means significant different ($P<0.05$)

Similar result was seen when litter MC increased from 30 to 40%. NH_3 ER decreased by zeolite application during the first week (p-value < 0.05) (Figure 3.7(a) and Table 3.13). On the first day of zeolite application, NH_3 ERR of high rate was significantly ($p<0.05$) higher than low and midrates. No significant emission reduction was found after one week of application for all three rates (p-value >0.05).



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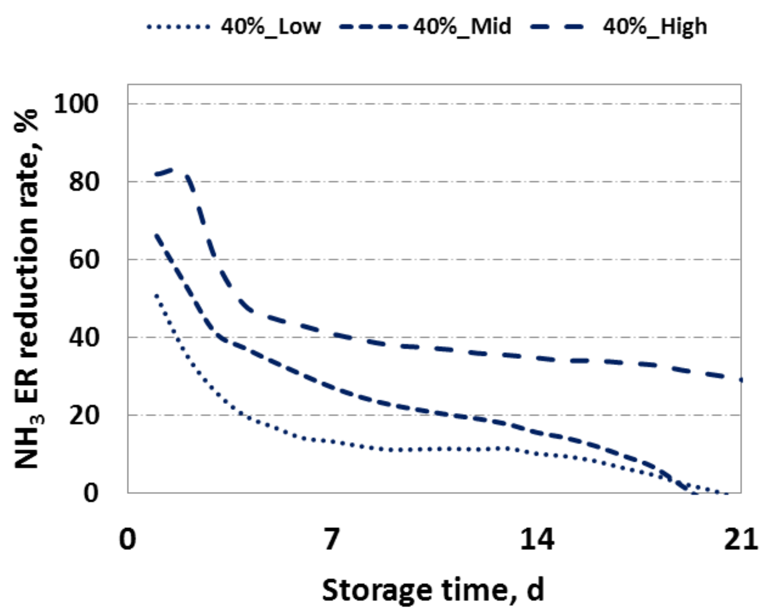
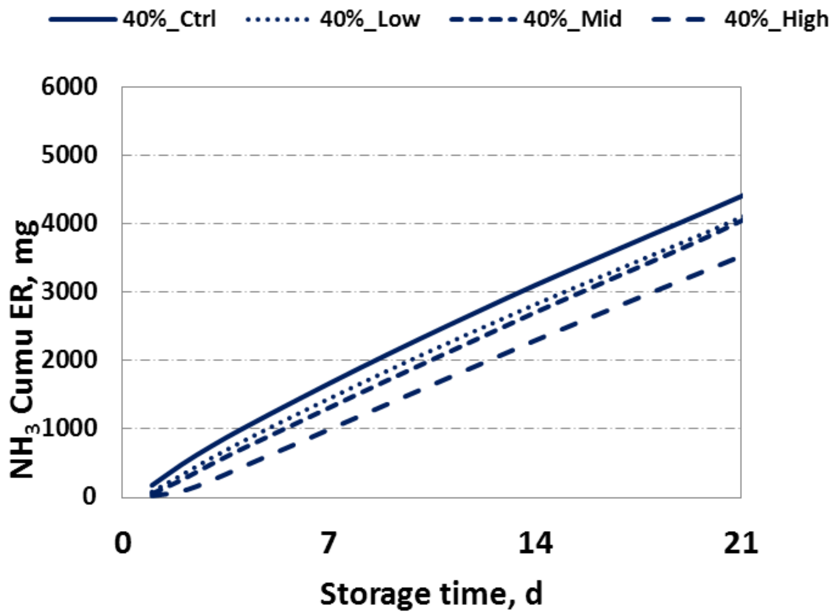


(b)

Figure 3.7: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 40% MC at four different zeolite application rates, 0(control), 366 (low), 732 (mid) and 1465 (high) g/m.

Figure 3.7 Continued



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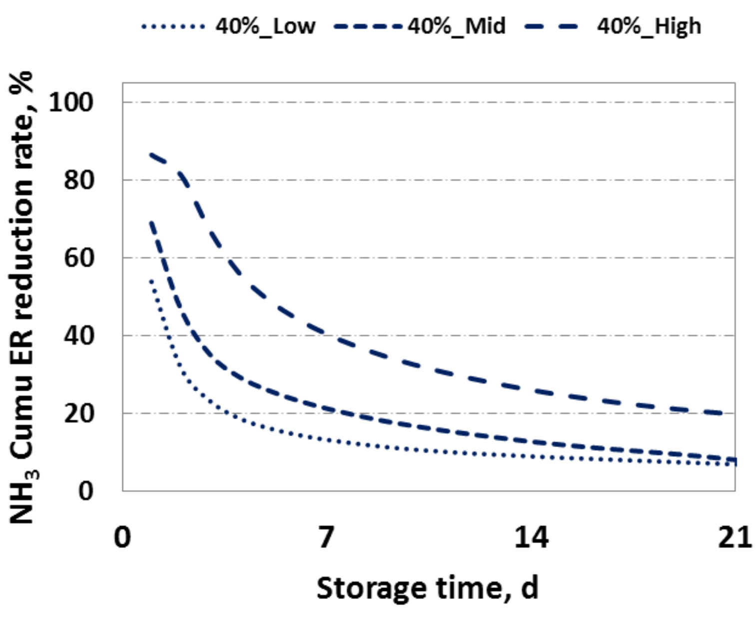


(d)

Table 3.13 NH_3 emissions from EVs with Zeolite treatment in four different application rates, 0(Ctrl), 366(Low), 732(Mid), and 1465 g/m (High) at 40% moisture levels (n=2)

Zeolite	Mean(S.E.)			
Age(day)	Ctrl	Low	Mid	High
1	177.4^{A}(87.7)	81.9^{A}(31.6)	55.2^{A}(19.6)	24.1^{A}(0.3)
7	220.1(151.8)	209.1(158.2)	203.2(172.8)	186.3(171.3)
14	195.7(150.0)	188.9(151.8)	196.7(167.8)	185.2(172.9)
21	188.5(128.1)	186.6(123.2)	205.5(139.8)	176.9(154.5)
23	197.8(115.6)	199.3(109.7)	233.5(136.6)	184.4(144.9)

Table 3.14: NH3 emissions reduction rate from EVs with Zeolite treatment in three different application rates 366 (Low), 732(Mid), and 1465 g/m (High) at 40% moisture levels (n=2)

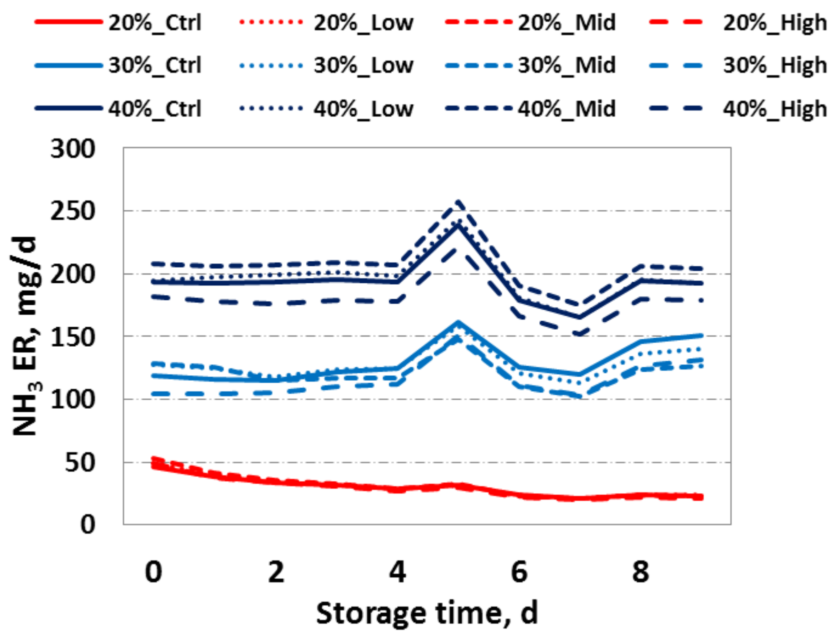
Zeolite(ERR)	Mean(S.E.)		
Age(day)	Low	Mid	High
1	0.51^{B}(0.07)	$0.66^{A,B}$(0.06)	0.82^{A}(0.09)
7	0.13(0.12)	0.27(0.28)	0.41(0.37)
14	0.10(0.09)	0.16(0.21)	0.35(0.38)
21	-0.01(0.04)	-0.09(0.00)	0.29(0.34)
23	-0.04(0.05)	-0.18(0.00)	0.23(0.28)

Note: NH_3 emissions were compared by each single day within 40% moisture, different superscript letter in that day means significant different ($P<0.05$)

The zeolite applications three different MCs can reduce 40% to 85% NH_3 emission on the first day depending on the application rate. Each Pair, Student's t-test was used to compare the NH_3 emission reduction rate. NH_3 emission reduction rate increased as zeolite application rate increased and a significant different was seen from the high application rate compared to low and mid application rate at both 20 and 30% MCs. No significant different was seen at 40% MC. After one week of zeolite application at 20% MC, high application rate had a higher NH_3 reduction rate compared to low and mid application rates (p-value < 0.05).; At 30% and 40% MCs, NH_3 reduction rates increased with increasing application rate. As the zeolite application rate increase from control (0 g/m) to high (1465 g/m) NH_3 ER decreased and NH_3 emission reduction rate increased from 0 to 85% during the three-week storage period. NH_3 emission reduction rate decreased as the moisture levels increased from 20 to 40%.

3.3.3 Effect of Active Charcoal on NH_3 Emission

Active charcoal application performances at three different moisture levels with three different application rates are shown in Figure 3.8.



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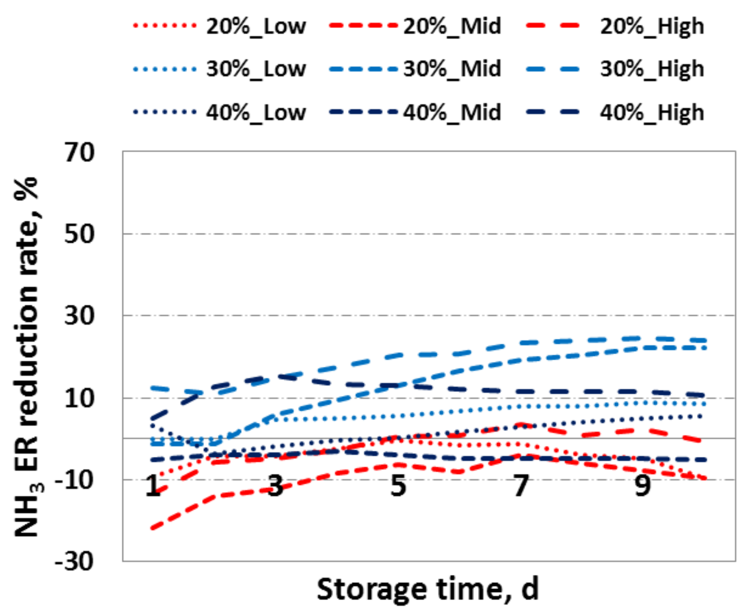
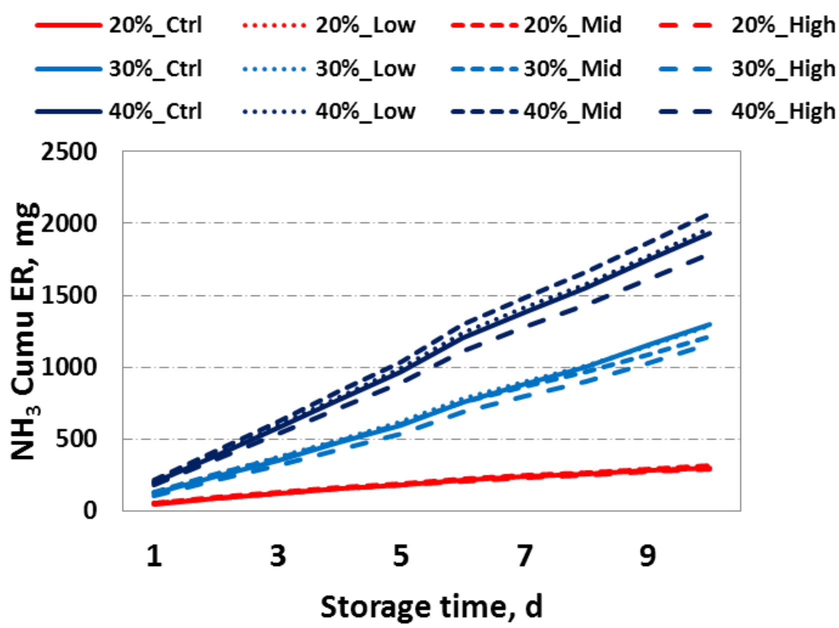


(b)

Figure 3.8: NH_3 daily emission rate (ER), daily ER reduction rate, cumulate emission (CE), and CE reduction rate of litter samples with 40% MC at four different charcoal application rates, 0(control), 366 (low), 732 (mid) and 1465 (high) g/m.

Figure 3.8 Continued



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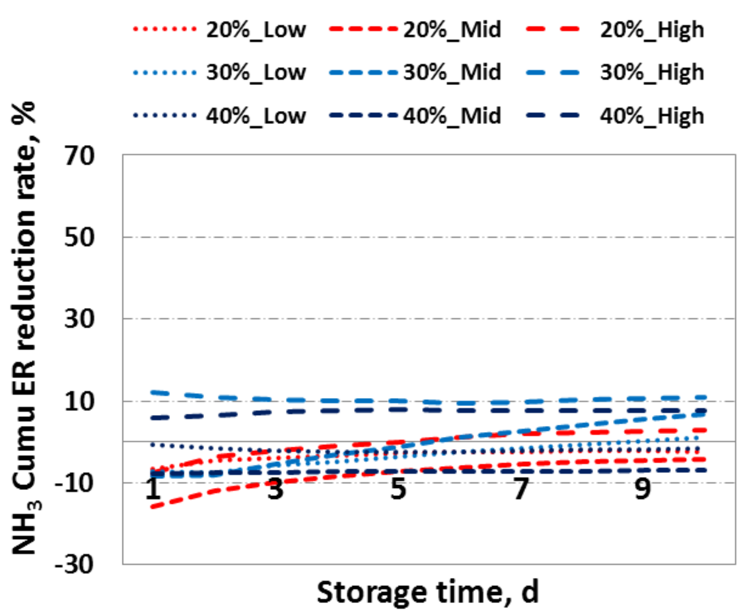

(d)

No significant NH_3 emission reduction (-20 to 20%) was obtained by using active charcoal to treat poultry litter (p-value > 0.05).

3.4 Conclusions

A laboratory study was conducted to evaluate the impact of litter amendment application and moisture on NH_3 emission from boiler litter. Three different moisture levels (20%, 30%, and 40%) and three amendments and rates (low, mid, and high) were tested. The following conclusions were made.

Litter moisture content had a positive influence on NH_3 emission rate. Higher moisture level led to higher NH_3 emission within 20 to 40% moisture level.

At the same comparable application rate, PLT showed a higher emission reduction rate than zeolite, and charcoal did not show a capability in reduce NH_3 emission.

Higher application rates demonstrated higher NH_3 reduction rates and longer effectiveness

PLT treatment at 30% MC has the lowest reduction rate compared to 20% and 40% MC.

Further studies are warranted and recommended to test the amendments performance under field conditions.

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Chapter 4

ASSESSMENT OF FREQUENT LITTER AMENDMENT APPLICATION ON NH_3 EMISSION FROM BROILERS OPERATIONS

4.1 Introduction

NH_3 is a very important atmospheric pollutant due to its impact on ecosystems. Major impacts associated with atmospheric NH_3 and its deposition includes eutrophication, soil acidification, and aerosol formation both in national and regional. The health effects of NH_3 are well known. NH_3 can be rapidly absorbed in the upper airway of human respiratory system. Also, NH_3 is an odorant with irritant properties. NH_3 is one of the criteria air pollutants (CAPs) defined by the Environmental Protection Agency (USEPA, 2013). Air quality associated with AFOs continues to be a high-priority issue for the animal agriculture in the U.S. For the broiler industry, concerns about NH_3 emission are multifaceted and include issues of live production performance, animal health, welfare, and environmental impacts.

NH_3 volatilizations from poultry litter are widely discussed (Nahm, 2005). NH_3 volatilization stems from microbial decomposition of nitrogenous compounds, principally uric acid, from animal feed operations (Chang and Chang, 1999). Microbe activities can be estimated by bacteria population density. (Okano et al., 2004) Several parameters that have effects on NH_3 emission from poultry litter such as litter moisture content, temperature, and litter pH level (Cabrera and Chiang, 1994; Tiquia and Tam, 2000; Liu et al., 2007; Atapattu et al., 2008; Miles et al., 2011). Also, nitrogen loss was significantly ($P<0.05$) greater for flocks reared in summer vs. winter (Coufal et al., 2006). To control the NH_3 emissions, litter amendments have been used to treat broiler litter. The most wildly used amendment is acidifier, when the temperature is held constant; pH determines the equilibrium between NH_4^+ and NH_3 in aqueous systems. A lower pH leads to a lower proportion of aqueous NH_3 and, therefore, to a lower potential of NH_3 volatilization. Acidification of animal manure to mitigate losses of NH_3 relies on this basic principle (Ndegwa et al., 2008). PLT application also have a significant improvement on the chicken death rate due to ascites ($P<0.05$) from 31.5% to 5.9% (Terzich et al., 1998). A layer manure with 38% zeolite placed on the surface of the manure reduced NH3 losses by 44% (Kithomie et al., 1999).

Litter amendment improved bird health and production due to lower NH_3 concentrations and bacterial loads in broiler houses (Terzich et al., 1998). Currently most litter amendments are only applied into the broiler houses prior to chick delivery due to potential bird toxicity and hazardous exposure. Litter amendments have been tested holding the NH_3 flux very well at the beginning of application, but at the end of the flocks, there was not much different seen from amendment treated vs. untreated houses (Miles et al., 2008). However, information on the efficacies of multiple litter amendment application during broiler grow-out on broiler NH_3 mitigation is meager. A systematic evaluation of frequent litter amendment application under controllable environment and field conditions was undoubtedly in order. Therefore, based on the thorough literature review and the result of our previous laboratory studies of NH_3 mitigation from poultry litter, it was found that the PLT and zeolite would be good poultry litter amendment in poultry houses. A laboratory project was conducted to quantify and delineate the efficacies of PLT and zeolite topically repeatedly applied at different rates on reduction of NH_3 emissions under commercial production conditions.

4.2 Materials and Methods

4.2.1 Environmental Chamber System

A lab scale study was conducted using six air emission measurement chambers at University of Delaware poultry research farm (Figure 4.1). The chambers each had dimensions of 74 cm (29 in.) length × 72 cm width (28 in.) × 74 cm (29 in.) height and were located inside an environmentally controlled room. The chamber walls were constructed with stainless steel. Fresh air to each chamber was supplied by a blower (model 1TDN6, Grainger, Lake

Forest, IL) through PVC pipe (5 cm inside diameter). The airflow rate through each chamber was measured with an air mass flow meter (RBM316703, Automotix LLC, Mission, KS) placed in the supply air stream. Airflow (3.4 to 6.8 m^3/hr-bird) through each chamber was adjustable via a damper on the inlet of the blower so that the concentration of target gases ($NH_3 \leq 25$ ppm and $CO_2 \leq 3{,}500$ ppm) inside the chamber could be controlled. One thermocouple (Type T, Cole-Parmer, Vernon Hills, IL) was placed in each chamber to measure dry-bulb temperature. Two plastic cups with tubing was placed underneath two nipple drinkers (High flow, Val-CO, New Holland, PA) to catch and divert any water leakage out of the chamber.

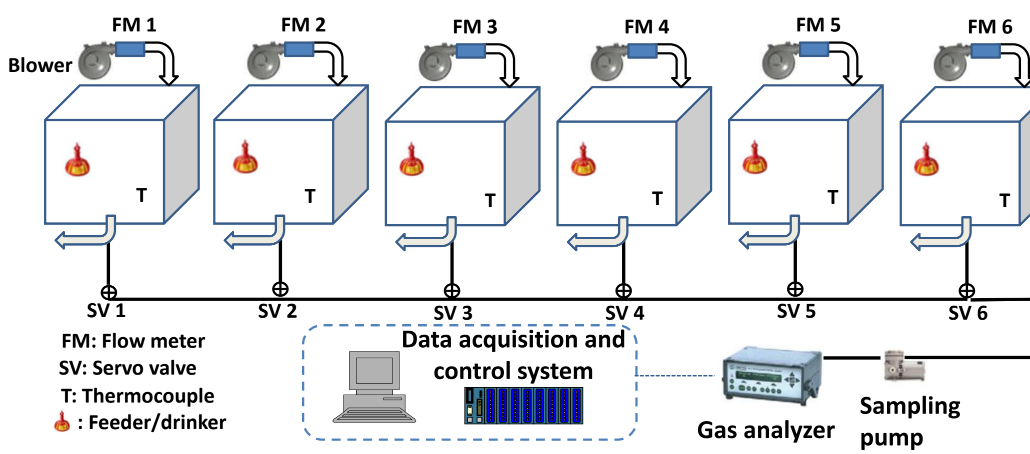


Figure 4.1: Schematic layout of the emission chamber system.

Samples of the exhaust air from each chamber were sequentially taken using an air sampling pump (model BTC-IIS, Parker Hannifin, Hollis, NH) at 5 min intervals, with the first 4 min for stabilization and the last 1 min for measurement. This sampling sequence yielded a measurement cycle of 35 min for the entire system (including 5 min for the ambient air). The successive sampling was accomplished through controlled operation of six solenoid valves (model 456654, Burkert, Irvine, CA). A Teflon filter (4.7 cm diameter, 5 µm pore diameter) connected to Teflon tubing (1.63 cm diameter) was placed in front of each solenoid valve. A photoacoustic multi-gas analyzer (model 1412, INNOVA AirTech Instruments A/S, Ballerup, Denmark) was used to measure NH_3 and CO_2 concentrations and dew point. The multi-gas analyzer was challenged weekly and calibrated, as needed, with zero, 25 ppm NH_3 (balanced with air) and 3000 ppm CO_2 (N_2 balance) span calibration gases. Analog outputs from the thermocouple and mass flow meters and digital outputs from the multi-gas analyzer were logged at 1 s intervals into a PC through a data acquisition module (USB-2416, Measurement Computing Corporation, Norton, MA). All measurements were recorded as the average of outputs over the 60 s intervals.

4.2.2 Experimental Design

Two flocks of female broiler chickens (Ross 708) were grown for this study. Each flock was raised on used litter bedding over a 7-wk grow-out period in six environmental chambers. Six birds were raised in each chamber and fed commercial diets ad libitum. The six chambers had identical temperature and lighting programs recommended. Based on a laboratory and preliminary test (Li et al., 2013), two PLT application rates (244 and 488 g/m^2) and two zeolite application rates (1464 and 2928 g/m^2 with two application intervals (once per week or once every two weeks) was served as experimental treatments. (Table 4.1)

Table 4.1: Chamber test arrangement and treatment strategy

Begin date(mm/yy)	End date(mm/yy)	Flock	Chamber	Treatment method(g/m^2)	Apply Bird age (day)	Bird age (age)	No. of birds
04/13	05/13	4	1 Ctrl	-	-	50	6
			2 PLT	244	21,28,35,42	50	6
			3 PLT	488	21,35	50	6
			4 Zeolite	1464	21,28,35,42	50	6
			5 PLT	244 or 488(on 28d)	21,28,42	50	6
			6 Zeolite	2928	21,35	50	6
05/13	06/13	5	1 PLT	244 or 488(on 27d)	20,27,41	44	6
			2 Zeolite	1464	20,27,34,41	44	6
			3 PLT	244	20,27,34,41	44	6

4 Zeolite	2928	20,34	44	6
5 Ctrl	-	-	44	6
6 PLT	488	20,34	44	6

Litter samples from the top 2.5 cm (1 in.) layer were collected on the day before PLT application and one day after each application and analyzed for pH. And the litter samples on the day after each application were analyzed for bacteria population density. Litter samples were mixed with a 10-fold (w/v) amount of buffered peptone water in a stomacher bag and agitated in a stomacher for 2 min. The resulting suspensions were serially diluted and 1-mL aliquots were plated on 3M™ Petrifilm™ Coliform Count, Aerobic Count and Yeast and Mold Count. The films were incubated at 37°C and colonies were counted after 24, 48 and 72 h for the three types of films, respectively. Production performance data for birds from each chamber, including feed consumption, body weight, and feed efficiency, were collected. Bird live weight was measured weekly. Two phase feeding strategy was used: starter feed from day zero to 13-d and grower feed from 14- to 50-d (Table 4.2). The feed added into each chamber was weighed and recorded. At the end of the flock, the birds were weighted again and feed conversion ratio (FCR) was calculated. Two litter samples (surface and bottom layers) were taken from each chamber for NH_3 nitrogen (NH_3-N), organic nitrogen (Org-N), total Kjeldahl nitrogen (TKN), pH, and moisture content (MC) by a (both state and federally) certified commercial laboratory (Midwest Lab, Omaha, NE). Manure MC was determined by drying the samples in an electric oven at 135 ^oC for 2 hr (AOAC International, 1990a). Total Kjeldahl nitrogen was measured using the improved Kjeldahl method (AOAC International, 1990b). NH_3-N was measured by the cadmium reduction method, and pH was measured with electrodes (AOAC International, 1990c). Footpad dermatitis was inspected at the end of each flock and scored using the scoring system in the Welfare Quality for broilers (Welfare Quality, 2009).

Table 4.2: Composition of the experimental diets (%)

	Crude Protein	Lysine	Methionine	Crude Fat	Crude Fiber	Ca	P	NaCl

Starter	22	1.2	0.52	3.5	4.0	1.45	0.7	0.85
Grower	20	1.0	0.35	3.5	4.0	1.45	0.5	0.75

4.2.3 Data Analysis

NH_3 emission rate (ER) was calculated as mass of NH_3 emitted from the chambers and partitions per unit time, of the following form:

$$ER = \frac{VR}{n} \times (C_e - C_i) \times \frac{17.031 g/mol}{22.414\ L/mol} \qquad (10)$$

where ER is hourly emission rate, g/bird-hr; VR is ventilation rate, m^3/hr; C_e is exhaust NH_3 concentration, ppm_v; C_i is inlet NH_3 concentration, ppm_v; n is bird number per chamber or partition.

Daily emission rates were the summation of the dynamic emissions over the 24 hr period:

$$Daily\ ER = \sum_{24}^{i=1} ER_i \qquad (11)$$

where Daily ER is daily emission rate, g/bird-d.

Cumulative emission by a given age was calculated based on the daily ERs:

$$CumuER_j = \sum_{i=1}^{j} Daily\ ER_i \qquad (12)$$

where $CumuER_j$ is cumulative emission at j-day of age, g/bird.

Reduction rates (RRs) of daily ER and cumulative ER were derived using the following equations:

$$RR_{ER} = \frac{(ER_{Control} - ER_{treatment})}{ER_{Control}} \qquad (13)$$

$$RR_{CumuER} = \frac{(CumuER_{Control} - CumulER_{treatment})}{CumuER_{Control}} \qquad (14)$$

Daily NH_3 ER, cumulative ER, and the reduction rates were calculated and used for the data analysis. Statistical analysis was performed using JMP Pro 10 (SAS Institute, Inc., Cary, NC). The data from the two flocks for the laboratory study were pooled and analyzed with multi-factor analysis of variance for the effects of application rate and flock.

4.3 Results and Discussion

4.3.1 Production Performances and Litter Properties

Production performances and litter (surface and bottom layer) properties of the broilers from the control and 5 treatments are shown in Tables 4.3, 4.4, and 4.5. And surface layer litter pH and bacteria density properties from the control and five treatments are shown in Tables 4.6, and 4.7.

Table 4.3: Production performances of broiler birds in a laboratory study (n=2)

Description §	Feed, kg		BW, kg		FCR		Foot pad score	
	Mean*	S.E.	Mean*	S.E.	Mean*	S.E.	Mean*	S.E.
Ctrl	3.63	0.13	2.40	0.14	2.17	0.13	0.55	0.21
weekly	3.54	0.04	2.44	0.13	2.02	0.18	0.45	0.21
biweekly	3.88	0.13	2.55	0.15	2.11	0.33	0.27	0.19
variable	3.63	0.13	2.47	0.17	2.06	0.14	0.36	0.15
weekly-Z	3.63	0.13	2.39	0.11	2.12	0.04	0.82	0.23
biweekly-Z	3.63	0.13	2.36	0.24	2.39	0.52	0.36	0.15

Notes: § BW: marketed bird body weight; FCR: feed conversion ratio; Ctrl: 0 g/m^2; weekly: 244 g/wk-m^2; biweekly: 488 g/wk-m^2; variable: 244 g/m^2 for week 3 and 6 and 488 g/m^2 for week 5; weekly-Z: 1464 g/wk-m^2; biweekly-Z: 2928 g/wk-m^2.

Table 4.4: Litter properties (at the end of the flocks, surface layer) of broiler birds in a laboratory study (n=2)

Description §			Ctrl	Weekly	Biweekly	Variable	Weekly-Z	Biweekly-Z
NH_3-N, %	As-is	Mean	0.77	0.84	0.89	0.76	0.73	0.77
		S.E.	0.01	0.13	0.18	0.13	0.17	0.08
	DM	Mean	1.25	1.50	1.69	1.34	1.12	1.20
		S.E.	0.04	0.19	0.52	0.30	0.28	0.13
Organic N, %	As-is	Mean	2.93	2.25	2.71	3.33	2.07	2.14
		S.E.	0.35	0.39	0.25	0.34	0.00	0.03
	DM	Mean	4.79	4.08	4.98	5.84	3.17	3.35
		S.E.	0.46	0.81	0.11	0.93	0.04	0.03
TKN, %	As-is	Mean	3.70	3.09	3.60	4.09	2.80	2.90
		S.E.	0.35	0.27	0.07	0.47	0.17	0.04
	DM	Mean	6.05	5.58	6.68	7.18	4.29	4.55
		S.E.	0.43	0.62	0.63	1.23	0.32	0.09
Phosphorus(P_2O_5) , %	As-is	Mean	2.59	2.08	1.95	2.05	2.05	2.18
		S.E.	0.25	0.03	0.23	0.29	0.36	0.03
	DM	Mean	4.24	3.75	3.58	3.55	3.15	3.41
		S.E.	0.31	0.16	0.02	0.30	0.59	0.06
Potassium(K_2O) , %	As-is	Mean	2.46	1.92	1.89	1.85	2.31	2.26
		S.E.	0.34	0.11	0.12	0.15	0.09	0.10
	DM	Mean	4.02	3.45	3.48	3.21	3.55	3.53
		S.E.	0.47	0.10	0.18	0.08	0.19	0.13
Sulfur(S), %	As-is	Mean	0.63^{B}	1.09^{A}	1.04^{A}	1.00^{A}	0.52^{B}	0.53^{B}
		S.E.	0.10	0.12	0.14	0.01	0.07	0.01
	DM	Mean	1.02^{B}	1.95^{A}	1.90^{A}	1.74^{A}	0.79^{B}	0.82^{B}
		S.E.	0.13	0.16	0.04	0.08	0.13	0.00
Sodium(Na), %	As-is	Mean	0.42^{B}	0.75^{A}	0.73^{A}	0.69^{A}	0.38^{B}	0.36^{B}
		S.E.	0.08	0.12	0.07	0.02	0.07	0.01
	DM	Mean	0.68^{B}	1.34^{A}	1.33^{A}	1.20^{A}	0.58^{B}	0.56^{B}
		S.E.	0.12	0.17	0.01	0.09	0.11	0.01
Salts, %	As-is	Mean	6.01	5.50	5.41	5.40	5.59	5.68
		S.E.	0.68	0.36	0.27	0.43	0.46	0.02
	DM	Mean	9.83	9.92	10.00	9.37	8.59	8.90
		S.E.	0.89	0.40	0.64	0.20	0.84	0.09
pH		Mean	7.70^{A}	6.15^{C}	$7.00^{A,B,C}$	$6.30^{B,C}$	$7.40^{A,B,C}$	$7.55^{A,B}$
		S.E.	0.30	0.05	0.70	0.20	0.40	0.05
MC, %		Mean	39.00	44.60	45.50	42.50	34.80	36.20
		S.E.	1.40	1.40	6.20	3.30	1.00	0.40

Notes: § NH_3-N: NH_3 nitrogen; Org-N: Organic nitrogen; TKN: total kjeldahl nitrogen; MC: moisture content; DM: dry matter basis.

* Row means followed by different superscript letters are significantly different ($p < 0.05$).

Table 4.5: Litter properties (at the end of the flocks, bottom layer) of broiler birds in a laboratory study (n=2)

Description §			Ctrl	Weekly	Biweekly	Variable	Weekly-Z	Biweekly-Z
NH_3-N, %	As-is	Mean	0.80	0.89	0.87	0.87	0.75	0.84
		S.E.	0.02	0.08	0.09	0.11	0.03	0.04
	DM	Mean	1.27	1.47	1.37	1.47	1.19	1.34
		S.E.	0.01	0.30	0.24	0.22	0.03	0.07
Organic N, %	As-is	Mean	1.94	2.12	2.02	1.89	1.73	1.72
		S.E.	0.10	0.33	0.22	0.19	0.05	0.03
	DM	Mean	3.08	3.41	3.13	3.18	2.76	2.75
		S.E.	0.07	0.13	0.11	0.25	0.08	0.02
TKN, %	As-is	Mean	2.74	3.01	2.88	2.76	2.48	2.56
		S.E.	0.12	0.25	0.14	0.08	0.07	0.01
	DM	Mean	4.35	4.88	4.50	4.65	3.94	4.09
		S.E.	0.06	0.17	0.13	0.03	0.11	0.04
Phosphorus(P2O5) , %	As-is	Mean	2.83	2.66	2.80	2.66	2.53	2.72
		S.E.	0.08	0.26	0.19	0.05	0.19	0.11
	DM	Mean	4.50	4.30	4.36	4.48	4.02	4.34
		S.E.	0.26	0.10	0.05	0.18	0.07	0.21
Potassium(K2O) , %	As-is	Mean	2.23	2.16	2.29	2.14	2.19	2.28
		S.E.	0.03	0.25	0.01	0.09	0.07	0.09
	DM	Mean	3.54	3.48	3.58	3.60	3.49	3.64
		S.E.	0.05	0.01	0.27	0.06	0.09	0.10
Sulfur(S), %	As-is	Mean	0.66^{B}	0.90^{A}	0.85^{A}	$0.78^{A,B}$	0.63^{B}	0.68^{B}
		S.E.	0.01	0.06	0.09	0.04	0.01	0.02
	DM	Mean	1.05^{C}	1.46^{A}	$1.31^{A,B}$	1.31^{B}	1.00^{C}	1.08^{C}
		S.E.	0.01	0.08	0.03	0.03	0.07	0.03
Sodium(Na), %	As-is	Mean	0.49^{C}	0.66^{A}	$0.61^{A,B}$	$0.59^{A,B,C}$	0.48^{C}	$0.52^{B,C}$
		S.E.	0.02	0.05	0.05	0.04	0.01	0.02
	DM	Mean	0.78^{C}	1.06^{A}	$0.95^{A,B}$	0.99^{A}	0.76^{C}	$0.82^{B,C}$
		S.E.	0.05	0.05	0.00	0.04	0.05	0.03
Salts, %	As-is	Mean	6.22	6.02	6.27	5.90	5.85	6.07
		S.E.	0.11	0.37	0.01	0.18	0.37	0.01
	DM	Mean	9.89	9.78	9.83	9.96	9.30	9.70
		S.E.	0.46	0.56	0.74	0.54	0.04	0.09
pH		Mean	8.15	7.80	7.85	8.00	8.20	8.05
		S.E.	0.05	0.00	0.05	0.10	0.20	0.25
MC, %		Mean	37.05	38.10	35.85	40.70	37.15	37.45
		S.E.	1.85	7.30	4.95	1.40	3.65	0.55

Notes: § NH_3-N: NH_3 nitrogen; Org-N: Organic nitrogen; TKN: total kjeldahl nitrogen; MC: moisture content; DM: dry matter basis.

* Row means followed by different superscript letters are significantly different ($p < 0.05$).

Table 4.6: Litter pH value from before and one day after amendment application (n=6)

Bird Age	Mean (S.E.)	Ctrl	Weekly	Biweekly	Variable	Weekly-Z	Biweekly-Z
28d	Before	7.9(0.09)	6.7(0.10)	6.5(0.01)	6.9(0.19)	7.9(0.12)	7.9(0.07)
	After	7.8(0.19)	6.0(0.06)	6.5(0.06)	5.6(0.01)	7.7(0.15)	8.0(0.13)
35d	Before	8.2(0.00)	6.6(0.24)	6.7(0.37)	6.3(0.28)	8.2(0.06)	8.2(0.00)
	After	7.8(0.01)	5.8(0.23)	5.4(0.31)	6.1(0.25)	7.8(0.15)	7.6(0.09)
42d	Before	8.3(0.05)	6.6(0.44)	6.3(0.45)	6.3(0.36)	7.8(0.25)	7.5(0.02)
	After	8.3(0.03)	6.0(0.35)	6.3(0.33)	5.9(0.28)	7.5(0.11)	7.1(0.26)
50d	End	7.4(0.48)	6.4(0.38)	6.8(0.60)	6.3(0.35)	7.0(0.31)	7.6(0.46)

Table 4.7: Litter bacteria density after one day of amendment application (n=2)

Type	Bird Age	Ctrl	Weekly	Biweekly	Variable	Weekly-Z	Biweekly-Z
Total	28d	7.50E+10	1.04E+10	2.91E+10	1.82E+10	5.40E+10	9.10E+10
	35d	7.50E+10	2.88E+10	8.10E+09	2.94E+10	7.30E+10	6.30E+10
	42d	4.45E+10	1.13E+10	2.20E+10	1.37E+10	5.05E+10	4.05E+10
	50d	1.80E+10	5.30E+10	1.46E+10	4.08E+10	4.65E+10	2.35E+10
Coliform	28d	9.00E+7	3.50E+6	4.55E+7	8.55E+7	8.30E+7	6.35E+7
	35d	1.44E+8	2.65E+7	1.30E+7	8.35E+7	1.31E+8	2.61E+8
	42d	3.10E+8	7.00E+6	4.00E+7	5.10E+7	1.02E+9	6.00E+07
	50d	1.65E+7	2.45E+8	9.50E+5	7.45E+7	1.15E+7	2.85E+07
Yeast Mold	28d	6.50E+5	1.08E+7	2.08E+6	2.80E+5	9.50E+4	1.20E+5
	35d	1.35E+5	2.64E+6	2.25E+7	1.70E+5	4.60E+5	4.50E+4
	42d	8.95E+4	7.60E+5	2.16E+6	1.35E+5	8.45E+4	1.55E+5
	50d	1.50E+5	6.92E+6	1.87E+6	1.20E+5	9.00E+4	4.00E+4

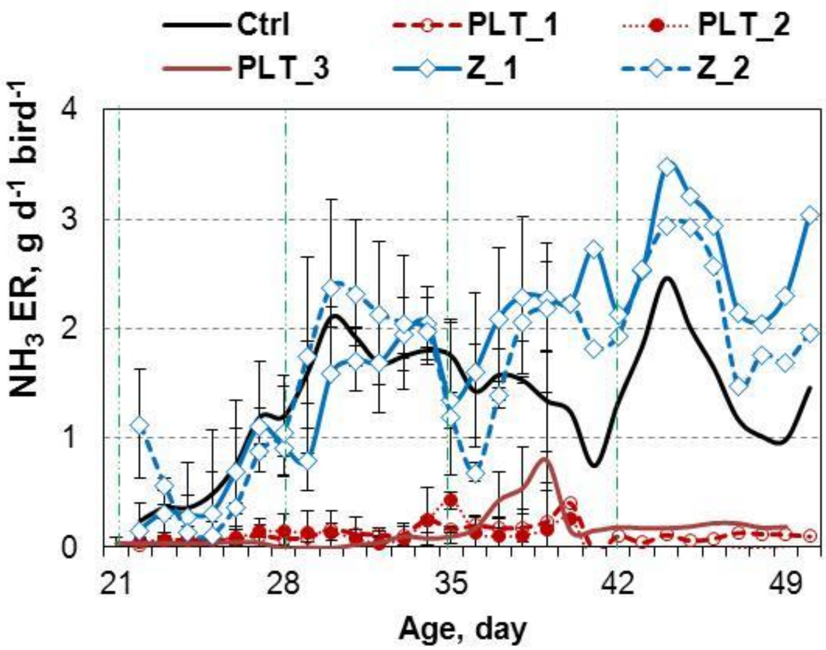
The sulfur and sodium contents were higher in the top layer litter with PLT treatment ($P<0.01$) and pH value (Chamber weekly and variable) were lower than control chamber ($P<0.01$). There was no significant difference seen from zeolite treatment applications. The pH values of PLT treated litter were lower one-day after each application and gradually increased with manure accumulation (Figure 2). The litter treated with PLT (all three strategies) had a lower pH than the control and zeolite treatment (from 7 to 8.5) chamber during boiler grow out period. The mean litter pH values of PLT treatments (weekly and variable) at the end of the flocks were 6.15and 6.30, which were significantly lower ($P<0.01$) than 7.70 of the control as well as zeolite treatment. The manure properties indicate that PLT applications led to lower pH, more NH_3-N content, and greater Org-N and TKN contents in the litter; zeolite applications wouldn't affect pH value but would led to a higher NH_3-N content, and greater Org-N and TKN contents in the litter. However, it shows that there was no significant difference between the PLT and zeolite applications on NH_3-N, Org-N, TKN, and moisture content at the end of the flocks (P>0.05). No significantly differences were obtained from the bacteria density property by 5 treatments. The lack of significance between the different strategies could be attributed to less replication (n=2) of the litter samples. Significant difference on NH_3-N, Org-N, and TKN could be expected if more chamber tests were taken and analyzed.

The mean pH values, NH_3-N content, Org-N and TKN contents were found to be about the same for all the two amendments and three treatment strategies. The sulfur and sodium contents were higher from the PLT treatments meanly due to sodium sulfate transferred with moisture leakage from the top layer. There were no significant differences among the PLT and zeolite treatments and control on body weight gain, feed conversion or footpad score (P>0.05).

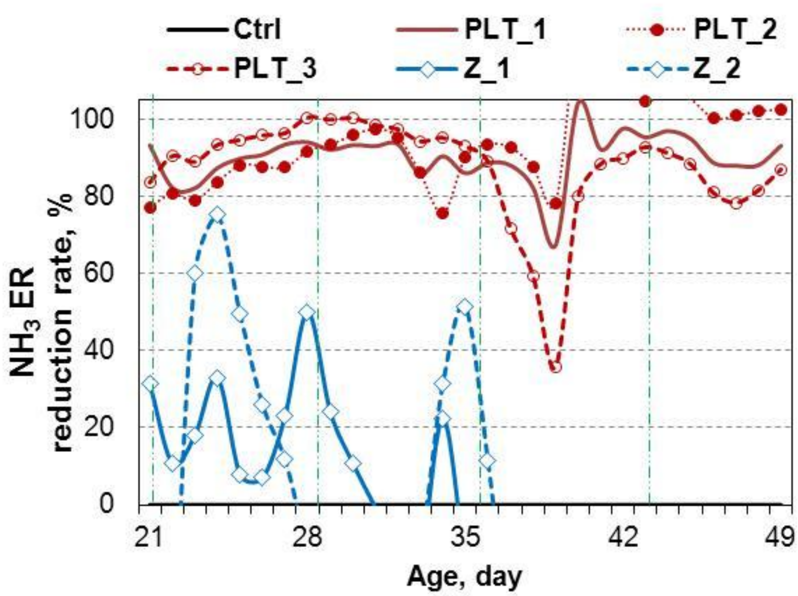
The pH value during the chicken grow out period was controlled under 7 from all the three PLT application method, but no difference was found between zeolite treatment versus control group. And the PLT treated sample also had a lower total and coliform density compared to untreated sample, which would also help decreasing bacteria activity and as a result can decrease NH_3 generation. No pH or bacteria influence was found from zeolite application at this chamber test.

4.3.2 Effect of Litter Amendment on NH_3 Emissions

Daily NH_3 ER and cumulative emissions over the 6-7-wk grow-out period for the control, PLT and zeolite treatments were summarized and shown in Figures 4.2 and 4.3. The NH_3 ERs of the birds with PLT treatment were significantly lower than the control and zeolite treatment treated chamber. The daily NH_3 ER was reduced dramatically for all grow out period with this topically repeatedly applied PLT. NH_3 ERs reduction was seen right after zeolite application and then increased to or over the control chamber NH_3 ERs. Birds with PLT treatment had significant lower daily NH_3 ERs and cumulative emissions after from this study, no NH_3 reduction were obtained from zeolite treatment. The dynamic reduction rate of daily NH_3 ERs fluctuated in the range of 59.5 and 100 % depending on the dissipation of the applied PLT and application strategies. The daily ERs of the seven days between two amendment applications were pooled and analyzed. The pooled reduction rates derived from the two flocks were from 83 to 100 % with the three PLT treatments chambers and from -28 to -50% with the zeolite treatments chambers during the seven days after amendments application. The reductions rates of cumulative emissions with PLT treatment on weekly application (from 88 to 91.5 %), biweekly application (from 81.5 to 94 %) and variable application (from 89 to 97 %) gave all high NH_3 reductions, but with zeolite treatment on weekly application (from -23.5 to 20 %) and biweekly application (from -20.5 to -5 %) were all lower than we expected from 22- to 49-d of age. Zeolite application showed an NH_3 adsorption on the first day application but it would release more NH_3 after all zeolite get saturated. (Witter and Lopez-Real, 1988)

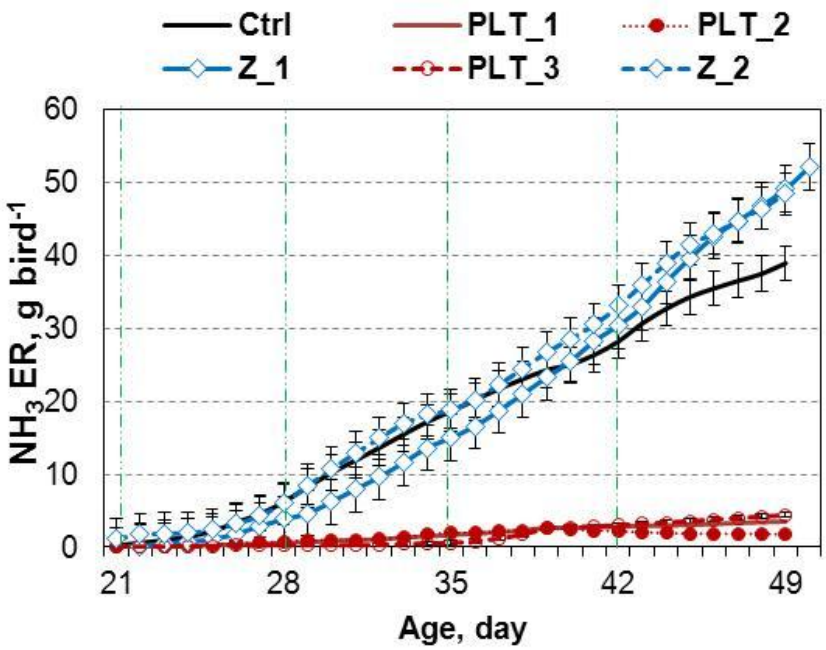


(a)

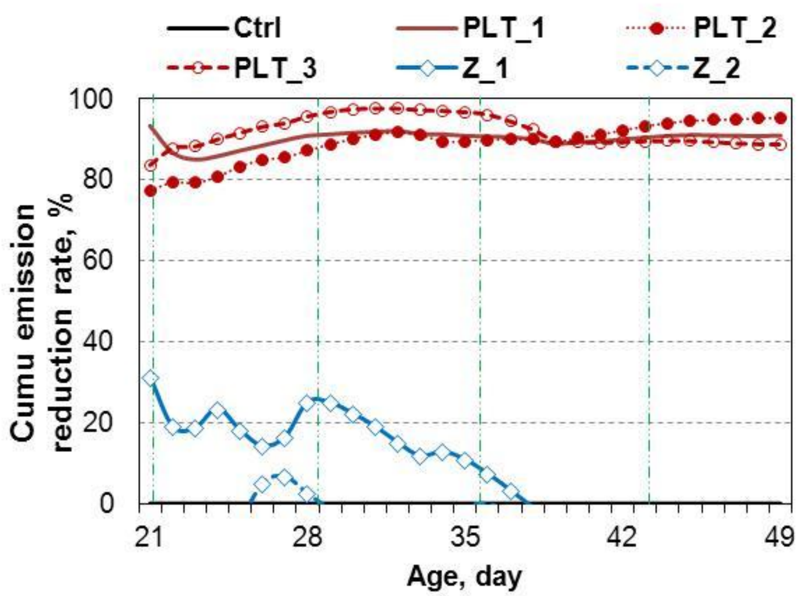


(b)

Figure 4.2: Mean (standard error) of NH_3 daily emission rate with PLT (three strategy) and Zeolite (two rates) treatment in a laboratory study (n=2).



(a)



(b)

Figure 4.3: Mean (standard error) of NH_3 cumulative emission with PLT (three strategy) and Zeolite (two rates) treatment in a laboratory study (n=2).

It should be noted that the promising efficacies of the PLT application in decreasing NH_3 emissions from broilers were quantified using relatively small laboratory-scale tests. Hence, these results should be considered as preliminary when attempting to apply such treatment agents in the field. In fact, it is highly advisable to expand the evaluation to field scale and verify the efficacies and more importantly assess the costs associated with such application before considering adoption at commercial production settings. But on the other hand, zeolite is not recommended in applying on the litter surface for reducing NH_3 emission.

4.4 Summary

A study was conducted that aimed to evaluate the impact of frequent PLT and zeolite application on NH_3 emission and litter properties. The following conclusions and observations were made.

Repeated application of PLT led to significant reduction in NH3 emissions from broilers.

Repeated application of zeolite didn't give a significant reduction in NH3 emissions from broilers. Zeolite application showed an NH3 adsorption on the first day application but it would release more NH3 after all zeolite get saturated.

The three different PLT application strategies perform a similar NH3 emission reduction property, and 89 to 95% cumulated NH3 reduction rate was obtained during 22- to 49-d in the laboratory scale study.

PLT and zeolite application showed no significant difference on body weight, feed conversion efficiency and foot pad quality.

Litter pH value was decreased by PLT applications with all three strategies. And NH3-N, Organic and total nitrogen contents in the litter were higher while less nitrogen was emitted as NH3. Sodium and sulfur contents were also increased by adding PLT.

No litter property changes were found with zeolite treatment.

The laboratory-scale findings of emission reduction by the additives should be considered to be preliminary if the additives are to be applied under commercial production settings. In fact, follow-up field-scale verification tests are warranted and recommended.

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Chapter 5

GENERAL CONCLUSION

From the experiment NH_3 adsorption analysis, zeolite was found to have a significant NH_3 adsorbing capacity. There is a significant potential for the zeolite as an adsorbent material for NH_3 removal from air stream. Zeolite NH_3 adsorbing capacity didn't change as moisture level range from 0 to 10%, or zeolite particle size increase from 1.41 to 2.38 mm.

Retention time was a factor that influences NH_3 adsorption significant ($p<0.01$) from zeolite column, a higher NH_3 adsorption rate can be expect with a higher retention time. As retention time increased from 0.73 to 1.29, the NH_3 adsorption capacity at 90% NH_3 concentration reduction rate increased from 1.40 ± 0.18 to 2.38 ± 0.15 (mg NH_3/g zeolite).

From the laboratory scale study, litter moisture content was found to have a positive effect on NH_3 emission from 20 to 40% moisture level. PLT treatment provided a higher NH_3 emission reduction rate compared with zeolite treatment, and charcoal treatment didn't show a capability in reducing NH_3 emission, at the same comparable application rate.

Consider either litter amendment (PLT or zeolite), higher application rate presented a higher NH_3 reduction rate on a same time period (at the same day) or longer effectiveness period till the same NH_3 emission reduction rate was reached.

PLT treatment with 30% moisture had the lowest reduction compared with 20% and 40%, due to PLT efficiency increase with moisture level increase but NH_3 generation also increased with moisture level increase.

Zeolite treatment with lower moisture could get a higher reduction rate, but zeolite was not preferred amendment compare with PLT at all moisture levels.

The reapply frequencies of PLT for 20% moisture level were 5, 7 and 12 days at low, mid and high application rate, respectively; for 30% moisture level were 9, 14 and 19 days at low, mid and high application rate, respectively; for 40% moisture level were 19, 20 and 24 days at low, mid and high application rate, respectively.

The following study was conducted to evaluate the impact of frequent PLT and zeolite application on NH_3 emission and litter properties in the broiler chamber scale. From this study, it was found that repeated application of PLT led to significant reduction in NH_3 emissions from broilers. But repeated application of zeolite didn't give a significant reduction in NH_3 emissions. NH_3 adsorption was observed on the first day of zeolite application but no significant different NH_3 emission was found after that.

A similar NH_3 emission reduction property was found from three different PLT application strategies, and 89 to 95% cumulated NH_3 reduction rate was obtained during 22- to 49-d in the laboratory scale study.

PLT and zeolite application showed no significant difference on body weight, feed conversion efficiency and foot pad quality. Litter pH value was decreased by PLT applications with all three strategies. NH_3-N, Organic and total nitrogen contents in the litter were higher while less nitrogen was emitted as NH_3. Sodium and sulfur contents were also increased by adding PLT. No litter property changes were found with zeolite treatment, on the other hand.

The laboratory-scale findings of emission reduction by the additives should be considered to be preliminary if the additives are to be applied under commercial production settings. Further study needs to be done to test the amendments performance in animal feeding operations. Field-scale verification tests are warranted and recommended.

Appendix A

NH_3 EMISSION DATA

Table A1. NH_3 emission rate (mg/d) from EVs with PLT treatment in four different application rates, 0(ctrl), 183(low), 366(mid), and 732 g/m^2 (high) in three different moisture levels (n=3)

ER(mg/d)		20%				30%				40%			
Age(day)		Ctrl	Low	Mid	High	Ctrl	Low	Mid	High	Ctrl	Low	Mid	High
1	Mean	81.7^{A}	8.4^{B}	3.8^{B}	5.1^{B}	63.4^{A}	4.7^{B}	2.4^{B}	0.4^{B}	64.4^{A}	4.0^{B}	2.2^{B}	1.2^{B}
	SE	16.3	2.7	0.7	2.6	14.3	0.9	0.7	0.2	19.0	2.1	0.7	0.7
2	Mean	51.7^{B}	5.8^{C}	1.5^{C}	1.9^{C}	51.6^{B}	3.6^{C}	1.3^{C}	-0.6^{C}	84.3^{A}	3.3^{C}	1.2^{C}	0.7^{C}
	SE	7.8	2.4	0.8	1.5	8.8	0.7	0.7	0.1	17.0	2.0	0.6	1.1
3	Mean	42.5^{B}	6.2^{C}	1.5^{C}	1.1^{C}	50.5^{B}	4.4^{C}	1.3^{C}	-0.5^{C}	82.5^{A}	5.6^{C}	1.4^{C}	0.6^{C}
	SE	6.9	2.4	0.9	1.1	7.1	0.9	0.7	0.1	14.8	2.9	0.8	1.2
4	Mean	37.5^{B}	7.1^{C}	1.6^{C}	0.9^{C}	51.6^{B}	6.6^{C}	1.5^{C}	-0.4^{C}	79.7^{A}	10.4^{C}	2.1^{C}	0.5^{C}
	SE	6.0	2.6	0.9	0.9	5.6	1.4	0.8	0.1	14.3	5.2	0.9	1.1
5	Mean	33.8^{B,C}	7.5^{C,D}	1.3^{D}	0.5^{D}	53.9^{A,B}	9.9^{C,D}	1.7^{D}	-0.7^{D}	80.6^{A}	14.8^{C,D}	2.5^{D}	0.3^{D}
	SE	5.4	2.8	1.0	0.9	5.8	2.4	1.2	0.3	14.5	7.7	1.1	1.2
6	Mean	32.4^{B,C}	8.6^{C,D}	1.7^{D}	0.5^{D}	56.0^{A,B}	14.7^{C,D}	2.4^{D}	-0.2^{D}	80.3^{A}	17.9^{C,D}	4.1^{D}	0.6^{D}
	SE	4.5	3.0	1.0	1.0	5.8	4.0	1.7	0.6	13.9	9.2	1.3	1.2
7	Mean	30.8^{B,C}	9.4^{C,D}	1.9^{C,D}	0.5^{D}	58.2^{A,B}	20.3^{C,D}	3.2^{C,D}	0.1^{D}	79.2^{A}	17.8^{C,D}	5.6^{C,D}	0.8^{D}
	SE	4.1	3.2	1.1	0.9	6.1	6.6	2.1	0.8	13.5	9.0	2.1	1.3
8	Mean	29.2^{B,C}	10.2^{C}	2.0^{C}	0.4^{C}	60.4^{A,B}	26.5^{C}	4.6^{C}	0.4^{C}	79.0^{A}	16.3^{C}	7.4^{C}	0.8^{C}
	SE	4.1	3.6	1.3	1.0	7.0	9.9	3.0	1.2	14.0	8.3	2.7	1.4
9	Mean	27.8^{C}	10.9^{C}	2.2^{C}	0.4^{C}	63.0^{A,B}	32.2^{B,C}	6.2^{C}	0.9^{C}	77.9^{A}	14.3^{C}	9.6^{C}	0.8^{C}
	SE	3.8	3.8	1.2	0.9	7.3	12.6	3.9	1.5	15.6	7.1	3.9	1.4
10	Mean	26.7^{B,C}	11.3^{C}	2.4^{C}	0.2^{C}	65.5^{A,B}	37.1^{B,C}	8.0^{C}	1.0^{C}	76.8^{A}	12.7^{C}	12.0^{C}	0.6^{C}
	SE	3.9	4.0	1.4	0.9	7.3	14.9	4.7	1.8	17.4	6.2	5.4	1.3
11	Mean	26.2^{A,B}	11.7^{C}	2.4^{C}	0.3^{C}	68.9^{A,B}	43.2^{A,B,C}	10.1^{C}	1.3^{C}	77.1^{A}	11.9^{C}	14.0^{C}	0.5^{C}
	SE	3.2	3.9	1.2	1.0	8.4	17.2	5.3	1.9	18.8	5.1	7.0	1.2
12	Mean	25.2^{B,C,D}	12.1^{C,D}	2.5^{C,D}	0.4^{D}	70.5^{A,B}	46.8^{A,B,C}	12.6^{C,D}	1.4^{D}	75.6^{A}	11.3^{C,D}	15.4^{C,D}	0.4^{D}
	SE	3.3	4.0	1.2	0.9	8.9	18.4	5.7	2.0	20.6	4.4	7.9	1.1
13	Mean	24.4^{B,C,D}	12.6^{C,D}	2.6^{C,D}	0.4^{D}	72.4^{A,B}	51.6^{A,B,C}	15.6^{C,D}	1.8^{C,D}	76.1^{A}	11.0^{C,D}	16.1^{C,D}	0.4^{D}
	SE	3.4	4.0	1.2	0.9	8.8	20.5	6.3	2.3	22.8	3.7	8.3	0.9
14	Mean	23.5^{A,B,C,D}	12.9^{C,D}	2.8^{C,D}	0.3^{D}	74.2^{A,B}	56.4^{A,B,C}	20.1^{B,C,D}	2.3^{C,D}	77.7^{A}	11.2^{C,D}	16.2^{C,D}	0.4^{D}
	SE	3.4	4.0	1.4	0.9	9.7	22.6	7.9	2.9	24.7	3.1	8.3	0.9
15	Mean	22.7^{B,C,D}	13.2^{C,D}	3.3^{C,D}	0.3^{D}	75.5^{A,B}	59.7^{A,B,C}	26.1^{A,B,C,D}	3.5^{C,D}	81.7^{A}	12.7^{C,D}	16.4^{C,D}	0.4^{D}

	SE	3.4	3.9	1.5	0.9	10.7	22.4	9.9	4.0	26.2	2.8	7.6	0.8
16	Mean	22.5^{B,C,D}	13.6^{C,D}	3.7^{C,D}	0.4^{D}	78.3^{A,B}	65.4^{A,B,C}	32.1^{A,B,C,D}	4.9^{C,D}	88.2^{A}	15.3^{C,D}	17.1^{B,C,D}	0.5^{D}
	SE	3.4	4.0	1.6	0.9	11.9	24.7	12.3	5.3	28.2	2.9	7.4	1.0
17	Mean	22.3^{B,C,D}	14.0^{B,C,D}	4.0^{C,D}	0.4^{D}	80.9^{A,B}	68.4^{A,B,C}	38.4^{A,B,C,D}	5.3^{C,D}	95.2^{A}	18.6^{B,C,D}	18.8^{B,C,D}	1.0^{C,D}
	SE	3.1	3.9	1.6	0.9	13.4	26.3	14.7	5.5	30.0	3.4	7.8	1.3
18	Mean	21.4^{B,C}	13.8^{B,C}	3.9^{C}	0.2^{C}	80.4^{A,B}	69.7^{A,B,C}	43.0^{A,B,C}	5.3^{C}	101.5^{A}	23.7^{B,C}	21.6^{B,C}	1.9^{C}
	SE	2.9	3.6	1.8	0.8	14.3	27.5	17.4	5.5	30.7	4.9	9.7	2.3
19	Mean	20.9^{B,C}	14.0^{B,C}	4.3^{B,C}	0.3^{C}	79.9^{A,B}	70.4^{A,B,C}	47.1^{A,B,C}	6.6^{B,C}	108.5^{A}	33.1^{A,B,C}	27.0^{B,C}	3.6^{B,C}
	SE	3.0	3.8	2.0	0.8	15.7	28.7	20.2	6.1	31.8	8.9	13.9	3.9
20	Mean	20.4^{A,B}	14.0^{B}	4.3^{B}	0.2^{B}	77.8^{A,B}	70.7^{A,B}	48.9^{A,B}	6.5^{B}	115.3^{A}	45.8^{A,B}	34.1^{A,B}	5.6^{B}
	SE	2.9	3.8	2.2	0.7	16.6	30.1	21.5	5.2	32.2	14.1	19.8	5.7
21	Mean	19.9^{B}	13.7^{B}	4.4^{B}	0.0^{B}	77.2^{A,B}	72.9^{A,B}	51.4^{A,B}	8.8^{B}	123.1^{A}	63.5^{A,B}	42.7^{A,B}	8.1^{B}
	SE	2.7	3.5	2.1	0.9	17.5	31.3	22.9	6.6	31.5	20.7	25.0	7.7
22	Mean	19.2^{B}	13.6^{B}	4.4^{B}	-0.1^{B}	76.7^{A,B}	74.4^{A,B}	52.6^{A,B}	11.7^{B}	128.9^{A}	79.7^{A,B}	53.8^{A,B}	11.9^{B}
	SE	2.7	3.5	2.1	0.8	18.8	33.3	24.1	7.4	31.9	26.3	30.8	10.0
23	Mean	19.0^{B}	13.7^{B}	4.9^{B}	0.0^{B}	76.7^{A,B}	73.0^{A,B}	54.9^{A,B}	15.3^{B}	134.4^{A}	93.6^{A,B}	66.0^{A,B}	16.3^{B}
	SE	2.6	3.3	2.1	0.8	19.3	31.8	25.0	8.4	30.9	29.0	34.9	13.2
24	Mean	20.0^{A}	15.1^{A}	5.3^{A}	-0.9^{A}	77.2^{A}	97.1^{A}	63.0^{A}	15.2^{A}	141.5^{A}	94.1^{A}	96.7^{A}	27.5^{A}
	SE	2.7	3.5	2.7	0.6	27.8	32.6	34.6	13.0	41.7	38.0	47.0	22.5
25	Mean	19.8	15.1	5.4	-0.9	76.8	98.1	63.5	21.3	144.9	106.0	108.7	36.9
	SE	2.6	3.4	2.8	0.4	28.2	32.4	35.4	18.0	40.3	36.1	48.2	29.9
26	Mean	19.4	15.2	5.5	-1.1	76.4	99.6	63.2	28.3	146.8	118.6	119.8	52.0
	SE	2.6	3.2	2.8	0.3	27.9	31.9	35.4	23.9	36.9	32.6	46.2	41.2
27	Mean	19.2	14.8	5.4	-1.0	77.3	103.4	64.6	33.5	150.8	130.0	129.4	70.1
	SE	2.3	2.7	2.5	0.5	28.2	33.2	36.3	28.0	35.6	28.6	42.7	53.7

Note: NH_3 emissions were compared by each single day, different superscript letter in that day means significant different ($P<0.05$)

Table A2. NH_3 emissions reduction from EVs with PLT treatment in three different application rates compare with control, 0(ctrl), 183(low), 366(mid), and 732 g/m^2 (high) in three different moisture levels (n=3)

ERR(%)		20%			30%			40%		
Age(day)		Low	Mid	High	Low	Mid	High	Low	Mid	High
1	Mean	0.88^{A}	0.95^{A}	0.92^{A}	0.92^{A}	0.96^{A}	0.99^{A}	0.94^{A}	0.96^{A}	0.98^{A}
	SE	0.06	0.02	0.05	0.03	0.02	0.00	0.02	0.02	0.01
2	Mean	0.88^{B}	0.97^{A,B}	0.96^{A,B}	0.93^{A,B}	0.97^{A,B}	1.01^{A}	0.97^{A,B}	0.98^{A,B}	1.00^{A,B}
	SE	0.06	0.02	0.04	0.02	0.01	0.00	0.02	0.01	0.01
3	Mean	0.84^{B}	0.96^{A,B}	0.97^{A,B}	0.91^{A,B}	0.97^{A,B}	1.01^{A}	0.94^{A,B}	0.98^{A,B}	0.99^{A}
	SE	0.07	0.02	0.03	0.02	0.01	0.00	0.03	0.02	0.01
4	Mean	0.80^{B}	0.96^{A,B}	0.97^{A,B}	0.87^{A,B}	0.97^{A,B}	1.01^{A}	0.89^{A,B}	0.97^{A,B}	1.00^{A}
	SE	0.08	0.02	0.03	0.03	0.02	0.00	0.06	0.02	0.01
5	Mean	0.77^{B}	0.96^{A,B}	0.98^{A,B}	0.82^{A,B}	0.97^{A,B}	1.01^{A}	0.84^{A,B}	0.96^{A,B}	1.00^{A}

	SE	0.10	0.03	0.03	0.03	0.02	0.01	0.08	0.02	0.01
6	Mean	0.73^{C}	$0.95^{A,B,C}$	$0.98^{A,B}$	$0.75^{B,C}$	$0.96^{A,B,C}$	1.01^{A}	$0.81^{A,B,C}$	$0.94^{A,B,C}$	1.00^{A}
	SE	0.10	0.04	0.04	0.05	0.03	0.01	0.10	0.03	0.01
7	Mean	$0.70^{B,C}$	$0.94^{A,B}$	0.98^{A}	0.66^{C}	$0.95^{A,B}$	1.00^{A}	$0.80^{A,B,C}$	$0.92^{A,B,C}$	0.99^{A}
	SE	0.10	0.04	0.03	0.09	0.03	0.01	0.11	0.04	0.01
8	Mean	$0.66^{B,C}$	$0.93^{A,B}$	$0.98^{A,B}$	0.57^{C}	$0.93^{A,B}$	1.00^{A}	$0.81^{A,B,C}$	$0.90^{A,B,C}$	1.00^{A}
	SE	0.11	0.05	0.04	0.14	0.04	0.02	0.10	0.05	0.02
9	Mean	$0.62^{B,C}$	$0.92^{A,B}$	$0.98^{A,B}$	0.50^{C}	$0.91^{A,B}$	0.99^{A}	$0.82^{A,B,C}$	$0.87^{A,B}$	1.00^{A}
	SE	0.11	0.05	0.04	0.18	0.05	0.02	0.09	0.07	0.01
10	Mean	$0.59^{A,B}$	0.91^{A}	0.99^{A}	0.44^{B}	0.89^{A}	0.99^{A}	$0.83^{A,B}$	$0.84^{A,B}$	1.00^{A}
	SE	0.12	0.05	0.04	0.20	0.06	0.03	0.08	0.08	0.01
11	Mean	$0.57^{A,B}$	0.91^{A}	0.98^{A}	$0.37^{B,C}$	0.87^{A}	0.99^{A}	0.84^{A}	0.81^{A}	1.00^{A}
	SE	0.11	0.05	0.04	0.22	0.06	0.02	0.08	0.11	0.01
12	Mean	$0.54^{B,C}$	$0.91^{A,B}$	$0.98^{A,B}$	$0.33^{C,D}$	$0.84^{A,B}$	$0.99^{A,B}$	$0.84^{A,B}$	$0.79^{A,B}$	1.00^{A}
	SE	0.11	0.04	0.04	0.23	0.07	0.03	0.07	0.12	0.01
13	Mean	$0.50^{B,C}$	$0.90^{A,B}$	0.98^{A}	$0.29^{C,D}$	$0.80^{A,B}$	0.98^{A}	$0.84^{A,B}$	$0.78^{A,B}$	1.00^{A}
	SE	0.10	0.04	0.04	0.24	0.07	0.03	0.06	0.13	0.01
14	Mean	$0.47^{B,C}$	$0.89^{A,B}$	0.98^{A}	0.24^{C}	$0.75^{A,B}$	0.97^{A}	$0.84^{A,B}$	$0.79^{A,B}$	1.00^{A}
	SE	0.10	0.05	0.04	0.25	0.09	0.04	0.05	0.13	0.01
15	Mean	$0.44^{B,C}$	$0.86^{A,B}$	0.98^{A}	0.21^{C}	$0.68^{A,B}$	0.96^{A}	$0.82^{A,B}$	$0.79^{A,B}$	1.00^{A}
	SE	0.09	0.05	0.05	0.24	0.10	0.05	0.05	0.12	0.01
16	Mean	$0.42^{B,C,D}$	$0.84^{A,B}$	0.98^{A}	$0.17^{C,D}$	$0.62^{A,B,C}$	0.94^{A}	$0.80^{A,B}$	$0.79^{A,B}$	1.00^{A}
	SE	0.09	0.05	0.05	0.24	0.12	0.06	0.06	0.11	0.01
17	Mean	$0.39^{B,C,D}$	$0.83^{A,B}$	0.97^{A}	$0.15^{C,D}$	$0.57^{A,B,C}$	0.94^{A}	$0.78^{A,B}$	$0.79^{A,B}$	1.00^{A}
	SE	0.09	0.05	0.04	0.25	0.12	0.06	0.06	0.11	0.01
18	Mean	$0.37^{B,C,D}$	$0.83^{A,B}$	0.99^{A}	$0.13^{C,D}$	$0.51^{A,B,C}$	0.94^{A}	$0.75^{A,B}$	$0.79^{A,B}$	0.99^{A}
	SE	0.08	0.06	0.04	0.26	0.13	0.07	0.06	0.09	0.02
19	Mean	$0.35^{B,C}$	$0.81^{A,B}$	0.98^{A}	0.12^{C}	$0.46^{A,B,C}$	0.92^{A}	$0.68^{A,B}$	$0.76^{A,B}$	0.98^{A}
	SE	0.08	0.07	0.04	0.26	0.15	0.08	0.08	0.09	0.02
20	Mean	$0.34^{C,D,E}$	$0.81^{A,B,C}$	0.98^{A}	$0.10^{D,E}$	$0.43^{B,C,D,E}$	$0.92^{A,B}$	$0.60^{A,B,C,D}$	$0.73^{A,B,C}$	0.97^{A}
	SE	0.08	0.08	0.04	0.27	0.14	0.07	0.10	0.10	0.03
21	Mean	$0.33^{C,D}$	$0.80^{A,B,C}$	0.99^{A}	0.07^{D}	$0.40^{B,C,D}$	$0.89^{A,B,C}$	$0.50^{A,B,C,D}$	$0.69^{A,B,C}$	$0.96^{A,B}$
	SE	0.07	0.07	0.05	0.28	0.14	0.09	0.13	0.12	0.04
22	Mean	$0.31^{C,D,E}$	$0.79^{A,B,C}$	1.00^{A}	$0.04^{D,E}$	$0.38^{B,C,D,E}$	$0.86^{A,B,C}$	$0.41^{A,B,C,D,E}$	$0.63^{A,B,C,D}$	$0.93^{A,B}$
	SE	0.07	0.08	0.05	0.29	0.14	0.10	0.15	0.13	0.05
23	Mean	$0.30^{B,C}$	$0.76^{A,B}$	0.99^{A}	0.05^{C}	$0.35^{B,C}$	$0.83^{A,B}$	$0.33^{B,C}$	$0.56^{A,B,C}$	$0.91^{A,B}$
	SE	0.07	0.08	0.05	0.29	0.14	0.11	0.14	0.14	0.07
24	Mean	$0.26^{B,C}$	$0.76^{A,B}$	1.04^{A}	-0.28^{C}	$0.29^{B,C}$	$0.87^{A,B}$	$0.37^{B,C}$	$0.38^{A,B,C}$	$0.86^{A,B}$
	SE	0.07	0.10	0.02	0.04	0.19	0.12	0.08	0.15	0.12
25	Mean	$0.25^{B,C}$	$0.75^{A,B}$	1.04^{A}	-0.31^{C}	$0.28^{B,C}$	$0.81^{A,B}$	$0.29^{B,C}$	$0.31^{B,C}$	$0.81^{A,B}$
	SE	0.07	0.11	0.01	0.06	0.20	0.17	0.05	0.14	0.15
26	Mean	$0.23^{B,C}$	$0.74^{A,B}$	1.06^{A}	-0.34^{C}	$0.28^{A,B,C}$	$0.75^{A,B}$	$0.20^{B,C}$	$0.23^{B,C}$	$0.73^{A,B}$
	SE	0.06	0.11	0.01	0.07	0.20	0.22	0.02	0.12	0.21
27	Mean	0.23	0.74	1.05	-0.38	0.28	0.71	0.13	0.17	0.63

SE	0.05	0.10	0.02	0.07	0.21	0.25	0.02	0.09	0.27

Note: NH_3 emissions reductions were compared by each single day, different superscript letter in that day means significant different (P<0.05)

Table A3. NH_3 emission rate (mg/d) from EVs with zeolite treatment in four different application rates, 0(ctrl), 366(low), 732(mid), and 1465 g/m^2 (high) in three different moisture levels (n=2)

Zeolite		20%				30%				40%			
Age(day)		Ctrl	Low	Mid	High	Ctrl	Low	Mid	High	Ctrl	Low	Mid	High
1	Mean	197.2^A	114.4^A	76.5^A	50.1^A	133.3^A	81.3^A	64.2^A	38.8^A	177.4^A	81.9^A	55.2^A	24.1^A
	SE	35.3	9.5	5.0	3.1	34.4	21.7	8.1	9.3	87.7	31.6	19.6	0.3
2	Mean	111.1	72.0	50.1	29.6	118.6	71.6	46.5	16.8	301.4	244.4	198.9	65.3
	SE	11.2	5.1	0.1	2.7	52.5	33.2	15.9	3.6	220.6	211.1	182.5	54.2
3	Mean	89.0	59.7	43.8	24.4	135.3	93.2	64.9	22.4	266.9	245.9	229.0	156.6
	SE	10.9	5.3	2.4	3.0	79.1	59.4	39.3	12.9	185.8	207.4	213.0	146.7
4	Mean	78.3	53.7	40.8	23.0	143.3	114.4	86.3	46.9	242.7	230.4	214.0	187.8
	SE	11.6	5.5	3.3	3.4	90.4	78.1	61.5	38.6	165.8	185.8	194.5	177.0
5	Mean	69.9	49.1	38.9	21.9	148.8	125.2	100.2	73.8	229.2	216.5	204.1	184.6
	SE	10.6	4.1	3.3	3.2	97.6	86.9	74.7	65.3	154.5	167.3	180.0	171.6
6	Mean	63.9	45.7	37.0	21.0	147.7	133.9	112.6	96.1	224.1	212.7	202.9	185.1
	SE	10.1	3.7	3.9	3.0	97.1	93.8	86.0	87.5	153.8	161.7	175.4	171.3
7	Mean	59.0	42.6	35.9	20.1	149.4	140.3	120.2	112.3	220.1	209.1	203.2	186.3
	SE	9.4	2.9	3.9	2.3	98.7	97.4	92.1	103.1	151.8	158.2	172.8	171.3
8	Mean	56.2	41.2	34.8	20.6	159.2	147.4	125.4	123.7	217.0	206.8	203.7	187.6
	SE	9.7	3.1	3.8	3.0	107.4	100.6	95.2	113.8	150.0	155.1	171.3	172.1
9	Mean	53.4	39.9	34.3	20.6	159.7	150.3	128.9	130.8	212.3	204.0	202.0	187.4
	SE	9.8	3.5	4.4	3.5	108.1	102.2	97.1	119.9	148.3	153.9	169.0	171.8
10	Mean	50.8	38.3	33.7	20.3	159.5	152.2	131.6	134.7	207.9	199.4	199.2	185.5
	SE	9.5	3.1	4.6	3.4	106.3	102.2	97.9	122.9	146.8	151.5	166.0	170.5
11	Mean	48.0	36.3	32.7	20.1	156.4	154.0	132.8	136.3	203.2	194.9	197.7	184.7
	SE	9.2	3.1	4.9	3.5	102.9	101.4	97.8	123.7	147.1	150.9	166.4	170.8
12	Mean	46.0	35.2	32.1	19.9	157.3	155.7	134.7	140.4	200.7	192.7	196.7	185.1
	SE	8.9	2.5	4.6	3.1	102.8	101.7	97.8	126.3	147.5	150.9	166.1	171.4
13	Mean	44.2	34.3	31.8	20.0	160.7	157.8	138.5	142.2	200.3	191.3	198.0	186.3
	SE	8.3	2.2	4.7	3.1	105.0	102.2	99.3	126.8	150.6	152.0	168.2	173.1
14	Mean	42.6	33.4	31.5	20.1	158.1	157.5	139.2	144.6	195.7	188.9	196.7	185.2
	SE	8.1	2.4	5.0	3.4	101.6	101.5	98.7	128.4	150.0	151.8	167.8	172.9
15	Mean	41.3	32.5	30.7	20.5	155.7	157.1	139.2	144.3	189.2	183.1	190.3	180.2
	SE	7.7	2.1	4.4	3.4	97.8	99.9	96.9	126.7	145.4	147.0	161.2	168.0
16	Mean	40.3	32.2	30.6	20.8	162.8	156.7	139.5	143.7	186.9	180.1	188.1	177.0
	SE	7.9	2.3	4.8	3.8	104.1	98.6	96.3	125.2	144.2	143.7	157.8	164.9
17	Mean	39.4	31.7	30.3	21.1	162.8	157.8	141.4	139.3	186.0	181.4	187.5	177.3

	SE	8.4	3.0	5.2	4.4	104.1	100.1	97.8	119.8	144.1	144.4	155.2	165.0
18	Mean	37.8	30.7	29.6	21.0	159.1	155.9	140.5	139.1	184.0	179.7	185.7	174.9
	SE	8.1	2.8	5.1	4.5	100.5	100.6	97.1	119.3	140.7	139.8	149.7	161.7
19	Mean	36.4	29.7	29.0	20.3	155.4	154.1	138.8	138.0	182.3	179.6	187.6	174.0
	SE	7.6	2.3	5.1	4.2	97.1	99.6	95.9	117.5	135.2	134.3	144.4	159.0
20	Mean	34.9	28.8	28.3	20.1	154.0	152.9	137.5	137.0	184.0	181.8	194.0	174.4
	SE	6.3	1.4	4.4	3.6	96.0	98.9	94.9	115.8	131.0	129.0	140.8	156.3
21	Mean	33.5	27.7	27.4	19.7	155.6	151.2	137.9	138.6	188.5	186.6	205.5	176.9
	SE	6.2	1.5	4.4	3.5	99.1	100.1	96.7	117.5	128.1	123.2	139.8	154.5
22	Mean	32.6	27.1	27.2	19.7	156.2	151.6	138.5	137.9	193.3	192.9	218.2	180.0
	SE	6.1	1.4	4.3	3.5	100.5	102.2	98.5	116.2	121.8	116.7	136.9	150.4
23	Mean	32.1	26.2	26.5	19.7	153.9	150.7	137.2	137.8	197.8	199.3	233.5	184.4
	SE	6.0	1.9	4.0	3.8	99.8	104.1	99.0	116.3	115.6	109.7	136.6	144.9

Note: NH_3 emissions were compared by each single day, different superscript letter in that day means significant different ($P<0.05$)

Table A4. NH_3 emissions reduction rate from EVs with zeolite treatment in three different application rates 0(ctrl), 366(low), 732(mid), and 1465 g/m^2 (high) in three different moisture levels (n=2)

Zeolite(ERR)		20%			30%			40%		
Age(day)		Low	Mid	High	Low	Mid	High	Low	Mid	High
1	Mean	$0.41^{C,D}$	$0.59^{A,B,C,D}$	$0.74^{A,B}$	0.39^{D}	$0.50^{B,C,D}$	$0.71^{A,B,C}$	$0.51^{B,C,D}$	$0.66^{A,B,C,D}$	0.82^{A}
	SE	0.06	0.10	0.03	0.01	0.07	0.01	0.07	0.06	0.09
2	Mean	$0.35^{A,B}$	$0.54^{A,B}$	0.73^{A}	$0.40^{A,B}$	0.59^{A}	0.84^{A}	$0.36^{A,B}$	$0.53^{A,B}$	0.82^{A}
	SE	0.02	0.05	0.00	0.02	0.05	0.04	0.23	0.26	0.05
3	Mean	$0.33^{B,C}$	$0.50^{A,B}$	$0.73^{A,B}$	$0.34^{B,C}$	$0.53^{A,B}$	0.83^{A}	$0.26^{B,C}$	$0.41^{A,B,C}$	$0.60^{A,B}$
	SE	0.02	0.03	0.00	0.06	0.02	0.00	0.26	0.39	0.27
4	Mean	0.31	0.47	0.71	0.24	0.45	0.74	0.20	0.37	0.48
	SE	0.03	0.04	0.00	0.07	0.08	0.10	0.22	0.37	0.38
5	Mean	0.29	0.44	0.69	0.20	0.40	0.63	0.17	0.34	0.45
	SE	0.05	0.04	0.00	0.06	0.11	0.20	0.17	0.34	0.38
6	Mean	0.28	0.42	0.67	0.14	0.33	0.54	0.14	0.30	0.43
	SE	0.06	0.03	0.00	0.07	0.14	0.29	0.13	0.31	0.37
7	Mean	0.27	0.39	0.66	0.10	0.30	0.47	0.13	0.27	0.41
	SE	0.07	0.03	0.02	0.06	0.15	0.34	0.12	0.28	0.37
8	Mean	0.26	0.37	0.63	0.08	0.29	0.46	0.12	0.25	0.39
	SE	0.07	0.04	0.01	0.01	0.12	0.35	0.11	0.27	0.37
9	Mean	0.24	0.35	0.61	0.06	0.27	0.43	0.11	0.23	0.38
	SE	0.07	0.04	0.01	0.01	0.11	0.36	0.10	0.26	0.38
10	Mean	0.23	0.33	0.60	0.05	0.25	0.40	0.11	0.21	0.38
	SE	0.08	0.03	0.01	0.01	0.12	0.37	0.10	0.24	0.38
11	Mean	0.23	0.31	0.58	0.02	0.23	0.38	0.11	0.20	0.37

	SE	0.08	0.03	0.01	0.00	0.12	0.38	0.10	0.24	0.38
12	Mean	0.22	0.29	0.56	0.01	0.21	0.36	0.11	0.19	0.36
	SE	0.10	0.04	0.02	0.00	0.11	0.38	0.10	0.23	0.38
13	Mean	0.21	0.28	0.54	0.01	0.20	0.36	0.12	0.18	0.35
	SE	0.10	0.03	0.02	0.01	0.10	0.37	0.09	0.22	0.38
14	Mean	0.20	0.25	0.53	0.01	0.18	0.33	0.10	0.16	0.35
	SE	0.10	0.02	0.01	0.00	0.10	0.38	0.09	0.21	0.38
15	Mean	0.19	0.25	0.50	0.00	0.17	0.31	0.10	0.14	0.34
	SE	0.10	0.03	0.01	0.01	0.10	0.38	0.08	0.19	0.38
16	Mean	0.18	0.23	0.48	0.03	0.19	0.34	0.08	0.12	0.34
	SE	0.10	0.03	0.01	0.02	0.07	0.35	0.06	0.17	0.37
17	Mean	0.17	0.22	0.46	0.03	0.18	0.35	0.06	0.10	0.33
	SE	0.10	0.03	0.00	0.01	0.08	0.32	0.05	0.13	0.37
18	Mean	0.17	0.21	0.44	0.03	0.17	0.33	0.05	0.07	0.33
	SE	0.11	0.03	0.00	0.02	0.09	0.33	0.03	0.10	0.37
19	Mean	0.16	0.20	0.44	0.03	0.17	0.32	0.03	0.02	0.32
	SE	0.11	0.03	0.00	0.03	0.10	0.33	0.01	0.06	0.36
20	Mean	0.16	0.19	0.42	0.03	0.17	0.31	0.01	-0.03	0.30
	SE	0.11	0.02	0.00	0.04	0.10	0.32	0.01	0.03	0.35
21	Mean	0.15	0.18	0.41	0.05	0.18	0.31	-0.01	-0.09	0.29
	SE	0.11	0.02	0.00	0.04	0.10	0.32	0.04	0.00	0.34
22	Mean	0.15	0.16	0.39	0.06	0.18	0.31	-0.02	-0.13	0.27
	SE	0.12	0.02	0.00	0.05	0.10	0.30	0.04	0.01	0.32
23	Mean	0.16	0.17	0.39	0.07	0.18	0.30	-0.04	-0.18	0.23
	SE	0.10	0.03	0.01	0.07	0.11	0.30	0.05	0.00	0.28

Note: NH_3 emissions were compared by each single day, different superscript letter in that day means significant different ($P<0.05$)

Appendix B

AGRICULTURAL ANIMAL CARE AND USE COMMITTEE LETTER

UNIVERSITY OF DELAWARE

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
AGRICULTURAL ANIMAL CARE AND USE COMMITTEE
Application for Use of Agricultural Animals In Teaching or Research

AACUC Protocol Number:

TITLE OF PROJECT: _ Mitigating ammonia emissions from broilers using litter amendment throughout full grow out

INSTRUCTOR/PRINCIPAL INVESTIGATOR

Hong Li ___________________ _ ______________ **7/27/2011**
Printed Name **Signature** **Date**

- -

Chapter 6(This section for Committee use only) **Application Approved (date)** _______

Application Rejected (date) ______________

Reason for Rejection ____________________________________

________________________________ ____________________
Signature, Animal Care and Use Committee **Date**

APPLICATION INFORMATION:

Title: Mitigating ammonia emissions from broilers using litter amendment throughout full grow out

Instructor/Principal Investigator: Hong Li

Address: 237 Townsend Hall

Telephone: 302-831-1652 Email: hli@udel.edu

Co-Investigators: Address:

Telephone: Email:

People involved in animal care for this protocol:

Name	Email	Office Phone #	Home/Cell Phone #	Received Animal Care Training	
				Yes	No
Hong Li	hli@udel.edu	3028311652	5154411331	X	

Has everyone listed above read the application and is familiar with the proposed work?

YES ■ NO □

If no, identify those needing to read application.

____________________ ___________________________ __________________

____________________ ___________________________ __________________

New or Three Year Review (mark one)

NEW ■ THREE YEAR □

If this is a 3 year renewal, what is the assigned existing protocol number?

____

Teaching or Research Application (mark one)

TEACHING □ RESEARCH ■

If TEACHING box was checked, select from the following:

Demonstration □ Laboratory □ Student Project □

Proposed start date:_8/1/2011_ **End date:9/30/2011_______**

Are all proposed animal care management procedures 1) defined as "pre-approved" by the Animal Care and Use Committee, or 2) part of the Standard Operating Procedures developed by the Animal Care and Use Committee for that particular species?

YES ■ NO □ to be determined by AACUC □

Has everyone been trained? YES ■ NO □

Who has not been trained?

____________________ ____________________ ____________________

____________________ ____________________ ____________________

Name the person responsible for conducting the training.
Hong Li

If after hours participation is required by students, please describe how this is being handled. (e.g. supervisors, assistants, etc.) Please include the times and days that students may be on site.
The students will be trained by Hong Li to properly handle the bird during weekend and after hours. If any emergency happens, students will call and report to Hong Li.

ANIMAL INFORMATION:

Common Name of the Animal Requested: Broiler Chicken

Amount Being Requested: 36

Source of Animals: Amick farm

Where are the animals being held: One small colony houses and one BLK houses with isolators

Briefly Describe the Goals or Objectives of this Application (use additional space as needed).
To determine repeated application of litter amendment (PLT) on ammonia (NH_3) emission from broilers. PLT is commonly used by broiler growers only at the beginning of the flock.

Please state or attach your animal protocol.
In total, 36 1-day-old female Ross 708 chicks will be collected and placed into one small colony houses with new wood shaving. The birds will have free access to water and regular feed. After 14 days, the birds will be transferred into isolation chambers in a block house and be housed in groups of six per cage till 42 days of age. 4 inch of litter form the block house will be put into each chamber. The total of six cages will be randomly assigned to three treatments with random design to minimize the cage effect. PTL™ (sodium bisulfate) will be manually applied to the litter surface in two chambers with a rate of 50 lb per 1000 ft^2 on the 21, 27, 33, 39, and 45 days of age. Another two chambers will receive PLT with a rate of 25 lb per 1000 ft2 on the 21, 24, 27, 30, 33, 36, 39, 42, and 45 days of age. The rest two chambers will not be applied with PLT. All six chambers will have same temperature set point and same air flow rate to meet the bird growth requirement during the grow-out period. NH_3 emissions of the three treatment throughout the grow-out will be evaluated.

How did you determine the number of experimental animals you are requesting? If you have a table showing treatment groups and animal numbers please insert here or include as an attachment.
Two reps for each treatment are required. Six birds per rep will be needed. So, total six reps and 36 birds will be requested.

Please verify that the research involving this protocol is new and is not a duplication of work already performed.
A literature search looking for duplication of work has been done. There is no such study has been done.

Does this procedure involve surgery? YES ☐ NO ■

If yes, explain in detail the surgery.

Will the animals experience pain? YES ☐ NO ■

If so, what is your pain management protocol? Please insert here or include as an attachment (euthanasia is an acceptable means of pain management): ______________________

Are drugs and/or medications being used? YES ☐ NO ■

If yes, describe what is being used. Include dosages and sites.

How often are animals monitored and how are sick or injured animals being handled?
The birds will be monitored daily. The sick or injured animal will be euthanized.

What is the method of euthanasia? Cervical dislocation

List the veterinarian who is on-call.

Dr. Miguel Ruano 302-831-1539
Name Telephone

Does this application need approval from OHS? YES □ NO ■

If yes, what form(s) are attached?_________________________

NOTE: OHS approval is required for experiments involving the administration of hazardous or biological materials such as pathogens, carcinogens, highly toxic, or radioactive materials.