# Construction and Evaluation of The Wind Tunnel Technique for Estimating Ammonia Volatilization from Land

*Laleh* Ghanizadeh Hesar[1*], *Ahmet* İnce[1], *Kamil* Ekinci[2], *Huseyin* Gücüm[3], and *Yasemin* Vurarak[4]

[1]Cukurova University, Faculty of Agricultural, Agriculture Machinery and Technologies Engineering, 01330, Adana, Turkey
[2]Isparta University of Applied Sciences, Faculty of Agriculture, Department of Agricultural Machinery and Technology Engineering, Isparta, Turkey; kamilekinci@isparta.edu.tr
[3]Adana Metropolitan Municipality, Seyhan, Adana, Turkey
[4]Eastern Mediterranean Agricultural Research Institute Directorate, Adana, Turkey; yasemin.vurarak@tarimorman.gov.tr

**Abstract.** Agriculture is mainly responsible for ammonia (NH3) volatilization. Among all agricultural activities, livestock and especially animal manures are the most important sources of NH3 emissions. Manure application which not only exacerbate greenhouse gas emissions, but also leads to eutrophication of water bodies. Many studies have shown that surface application of manure can lead to large ammonia losses and run off, on the other hand that tillage can substantially reduce these losses. It is necessary to determine ammonia flux from manure-amended soils to improve management manure handling practices for minimizing agriculture's impact on the environment. From this point of view, one of the direct measured method was used to determine this volatilization. The objections of this work were: i) The design, construction, physical calibration, and operation of the little wind tunnels. ii) Recover ammonia loss from bovine slurry by little wind tunnel method. iii) Determine the effect of slurry application depth on ammonia emission. The little wind tunnel system consisted of plastic canopy covering the treatment area (2 m long by 0.5 m wide). By was using a fan, it was imitated the natural wind speed in the test area (1-1.5 m/s). Nitrogen losses were measured with this method in surface application, 50 mm and 100 mm subsurface. In the surface application, the highest ammonia emission was observed. It was approximately 68% higher in compared to another methods. There is significantly (P=0.05) different in the ammonia emission, between the surface apply method and injection manure in soil methods. But There isn't any significantly different between ammonia emission amount in injection subsurface methods (100 mm and 50 mm deep).

## 1 Introduction

The most important problem facing the world is the inability to provide enough cheap food to people while the world population is increasing. To solve this problem, it is aimed to get more efficiency from the unit area for this, it is aimed to intensify the use of input. Fertilization has a large important share in agriculture [1]. In the consumption of nitrate-based fertilizers, increasing have been reported by FAOSTAT around 41% between 1985 and 2021. Which has reached around 109 million ton all world in 2021 [2]. The increase in animal stocking and in the price of chemical fertilizers encourage farmers to use animal manure and slurry [3]. Animal manure especially liquid manure is a rich source of nutrients for crops. In the other hand, ammonia ($NH_3$) from animal manure at high concentrations and emission rates is one of the most important agricultural environmental problems related to human and animal health since it causes ecological damage [4].

N can be lost the atmosphere or water source before uptake by plants. Agriculture is mainly responsible for ammonia ($NH_3$) volatilization. Among all agricultural activities, livestock and especially animal manures are the most important sources of $NH_3$ emissions. Agriculture represents the major emitter of ammonia ($NH_3$) and is responsible 94% of total emission in eu-28 in 2016 [5]. According to reports, livestock practices participate in ammonia losses in housing activity is 6%, in storage 28%, in land application 53% and 6% the others [6].

It is necessary to evaluate manure management and application practices for minimizing agriculture's impact on the environment. For this goal, first of all, it's necessary to quantify this loss. Studying ammonia volatilization requires specialized research equipment because volatilization is a physic-chemical process controlled by factors such as soil PH, soil temperature, tillage, manure composition, wind speed, soil texture, plant uptake, leaching and so on [7].

There are some methods to determine ammonia flux from farmland after fertilization. The indirect methods which mainly refers to the soil ammonia balance by determined amount of soil residue, plant absorption, leaching and so on. And the direct methods are i) micrometeorology, ii) closed chambers, and iii) small wind–tunnel techniques [8]. Micrometeorology method is based on the measurement of the density of the vertical gas flux in the free air above the fertilized surface [9]. This

*Corresponding author: lale.ghanizadeh@yahoo.com

method is widely accepted, but have been required large treatment areas of uniform topography to (>50 m diameter circles) and stable wind profiles are some disadvantages of this method. Besides that, need for large areas commonly prevents replication and limits investigations to only one treatment. Closed chamber method is cylindrical an open-ended bottom with little diameter, that is covered treatment area. Ammonia emission measurement is base of acid trap system. Small, lightweight, easy transportation, relatively cheap are advantages of this system [10]. Small wind tunnels offer advantages of mimic environmental situation, easy transportation, study of several treatments, replication and comparisons among treatments. The basic design of the wind tunnel is given by lockyer [11]. They have been extensively used this technology to measure ammonia emissions over a surface and compare emission rate between different and effect soil temperatures. Christensen and Sommer studied about to measure the recovery efficiencies of this technique. They reported obtained recoveries of 70-80% with slurry [12].

## 2 Materials and Methods

The aim of this study to determine the effects of the application methods of liquid manure on $NH_3$ emissions rate from farm land. This experiment was carried out in 2021 to 2022 at the Cukurova University, Department of Agricultural Machinery and Technologies Engineering, Adana, Turkey. A software has been used to design the small wind tunnel and simulate ventilation performance in it. The wind tunnel including a transparent plastic part with 2 meters long by 0.5 m wide for covered 2 $m^2$ area. The "U" shaped canopy was attached to sheet metal cylinder. To mimic natural wind, an electric fan allowed air across the enclosed area by velocity ranges of 1 m/s. In one study determined there was a 15% increase in total available N lost for every 1 $ms^{-1}$ increase in wind speed following with pig and cattle manure application [13]. Treatment area was prepared at 2 square meter area for each experiment. The treated area included surface apply or traditional method, 50 mm subsurface, 100 mm subsurface, was repeated three times for treatment during each interval of measurement. The amount of volatilized NH3 after of different application methods of slurry in soil was assessed under constant and controlled environmental conditions. Measurements were conducted over a 48h period. Air temperature and wind speed in the tunnel were also recorded.

### Construction

The basic design of the wind tunnels is covered treatment area and mimic environment factors. The clear plastic canopy is made of polycarbonate (2 m long by 0.5 m wide by 0.48m high) that covered 1 $m^2$ area. The polycarbonate sheet was flexed into U shape and were located at a rectangular frame which was made from aluminium measuring 5× 5× 0.3 cm (thickness). The canopy attached to sheet metal cylinder has an internal diameter of 25 cm, length of 100 cm. This cylinder was housing a fan and a cross–sectional air–sampling device. The electric fan, 25–cm diameter aluminium impeller with seven blades set at a 15 pitch to draw air across the enclosed area by velocity ranges from 0.5 to 5 $ms^{-1}$. Wind tunnel system had capabilities to mimic natural wind speeds. (Fig 1)

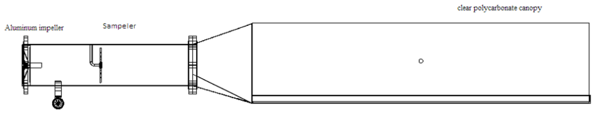


**Fig 1.** Wind tunnel side view

The star sampler device with eight legs was mounted in the cylinder section. Each leg extends 9 cm from a hollow hub that served as a vacuum manifold. Air entry through the end of each leg and two holes those were drilled on legs, at equal distances from the hub (Fig 2). The star sampler was connected to the gas scrubbing bottle. Ammonia concentrations in the air were measured using acid trap, flow meters, and vacuum pumps.

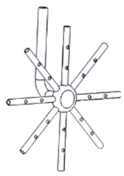

**Fig 2.** Star sampler device

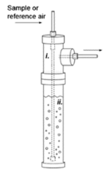


**Fig 3.** Acid trap

The gas scrubbing bottle, containing 120 ml of %2 boric acid, was used as trap to reaction with ammonia in the sampling air (Fig 3) [14]. A small vacuum pump bubbled sampling air through Acid Boric (acid trap) constructed from PVC tubing. The air flow rate through the acid traps was set at 5 L $min^{-1}$. The volume of air passing through the gas scrubbing bottles was measured with a gas–flow meter. The amount of ammonia flowing in the medium was found by the amount of ammonia trapped in the boric acid divided by area on the basis of time.

### 1.2 Simulation

A simulation program has been used to simulate ventilation performance. Velocity and pressure were simulated to define the aerodynamic condition inside the tunnel.

As the figure, the results of symmetric behaviour can be seen of the flow pattern. Flow speed in the entrance part of the tunnel was measured around 0.8 $ms^{-1}$ and this measure was recorded around 1.2 $ms^{-1}$ during the canopy. Velocity and pressure simulated were performed, to define the air flow condition inside the tunnel (Fig 4).

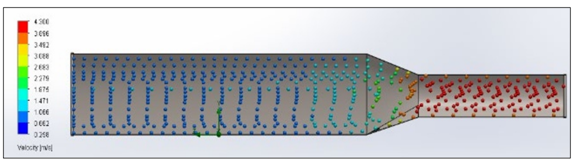

**Fig 4.** Simulated of velocity profile inside the wind tunnel

In the length of the tunnel reported a steady state condition in velocity and pressure. In canopy section the air pressure was almost constant. These almost constant boundary conditions at the main flow are likely to create a constant wind speed through the section. The air velocity and pressure profile shown in Fig (5,6).

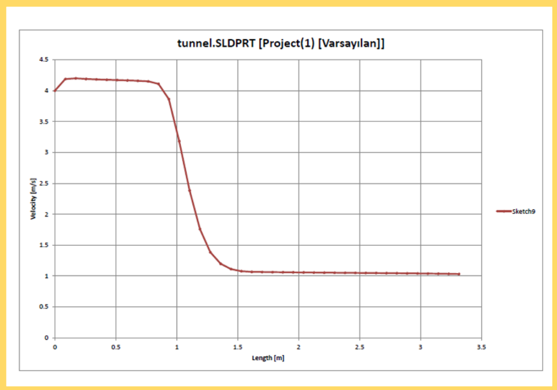


**Fig 5.** Simulated of velocity profile inside the wind tunnel

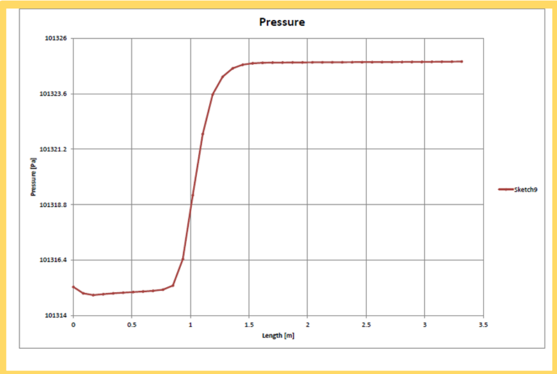


**Fig 6.** Simulated of pressure profile inside the wind tunnel

Five vertical cross-sections were chosen for the measurements, entrance of the tunnel, 1/4 (x=50 cm), 1/2 (x=100 cm), 3/4 (x=150 cm) of length of the canopy and output of tunnel respectively. Pressure bulk average, velocity average and mass flow rate were measured for each one of the points (Fig 7).

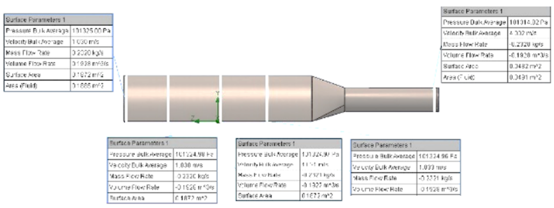

**Fig 7.** Pressure bulk average, velocity average and mass flow profiles at the start, three equal distances in canopy and end point of the emission section in the wind tunnel for nominal velocity values of 1.2 m s$^{-1}$.

### 1.3 Experimental Setup

Organic fertilizers used in the experiment were bovine slurry, which was collected from barn by a scraper and passing through the separator. Fertilizers were applied at a rate of 85 kg ha$^{-1}$ of total N. Experiments included three methods treatments applied to 2 square meter sample areas for each one. Split-plots was designed by separate random assignments of levels of application methods. These methods were surface apply or traditional method, 50 mm subsurface, 100 mm subsurface. Tunnel set–up involved attaching all electrical connections to power and was placed the canopy over the treated area at the same time was activated vacuum pumps to bubbled sampling air in gas scrubber. The fan was set to allow air flow velocity in the middle of canopy as 1 ms$^{-1}$. Wind speed was measured by a thermal (hot–wire) anemometer. Air flowmeter (airflow Tech. Prod. Inc., model 8455, Netcong, N.J.) mounted in the e entrance of acid trap tube which monitors sampling air volume flow rate through the acid trap. Scrubber flow–meter rates were 5 L min$^{-1}$. Ammonia losses from the treated area was calculated from the ammonia concentrations in the outlet air streams and the airflow through the tunnel.

Measurements were commenced within 15 min of completing treatment application. The treatments are normally applied to a 1.7 m length of the 2 m canopy [15].

Experiments were run for 48 h and Practice to collected samples was doing every 3 hours over activity. Every 3 hours, the trapped acid sent to the laboratory for analysis and determined ammonia solution in it and the new acid was replaced, and this work continued over collection period. In this procedure the distilled ammonia is trapped in 2% boric acid and titrated with standard 0.005 N H2SO4 [16].

The amount of ammonia flowing in the medium (kg $NH_3$-N ha$^{-1}$d$^{-1}$) was found by the amount of ammonia trapped in the boric acid trap divided by area on the basis of time. duct. The flux was then calculated using the Eqn (1,2).

$$f = (r \times c_a)/10^2 A \quad (1)$$

$$c_a = (c_s \times v_s)/v_a \quad (2)$$

f (kg $NH_3$Nha$^{-1}$ d$^{-1}$) net daily ammonia volatilization flux, $c_a$ atmospheric concentration of $NH_3$-N (mg N m$^{-3}$) at the wind tunnel, $c_s$ (mg N L$^{-1}$) is the measured concentration of $NN_3$-N in the acid trap solution, $v_s$ (L) is the measured volume of acid trap solution, $v_a$ (m$^3$) is the measured volume of air passed through the acid trap solution, r (m$^3$ d$^{-1}$) is the air volumetric flow rate through the wind tunnel and A (m$^2$) is the soil area covered by the wind tunnel.

The air speed along the X-axis and along the Y-axis was measured with hot wire anemometer and rotating-vane anemometer. For this purpose, measuring points were placed on the side and above the tunnel in the middle of the canopy for reference and the other was placed in tunnel output

## 3 Results

A standard measurement technique for measuring emissions from area sources is needed. One of the key parameters that must be standardized include wind velocity profile in the tunnel. In this study it was able to imitate the characteristics of the environment, under the small wind tunnel by keeping the wind speed constant. The velocity profile in the tunnel provides fairly consistent flow. The velocity near the bottom of the wind tunnel was slightly less than that measured in the middle and top of the tunnel. There was no significant difference between the height of the velocity boundary layer in the small wind tunnel. The velocity is around 1.2 $ms^{-1}$ in the middle (Fig 8).

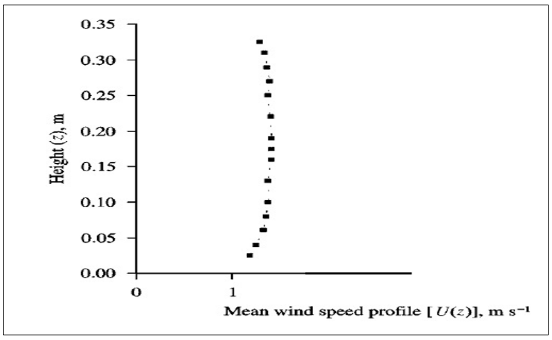


**Fig 8.** Mean vertical air velocity measured in canopy at $ms^{-1}$

Based on the values recorded during the experiment, ammonia flux of treatment area was seen at the peak point in the early hours after application. The amount measured in the first three hours after applying 12($kgNH_3$-$Nha^{-1}d^{-1}$) in the surface apply method, 4.82 (kg $NH_3$-N $ha^{-1}$ $d^{-1}$) in the 50 mm subsurface and apply method, 3.84 (kg $NH_3$-N $ha^{-1}d^{-1}$) in the 100 mm subsurface method. Around 30% of ammonia emission happened at the first three hours after application. It was around 40% at first six hours after application and flow that by 50%-60% at first nine hours.

All statistical analysis was conducted using SPSS Statistical Software. There was a close association between application method and ammonia volatilization in studies. Ammonia emission following land spreading of animal slurry seems to depend on type of application technique, as shown in (Fig 9). For the interpolation of the amount of emitted $NH_3$ measured in each application method, three different mathematical models were used. A strong linear relationship was observed between the $NH_3$ emission and time after starting experiment.

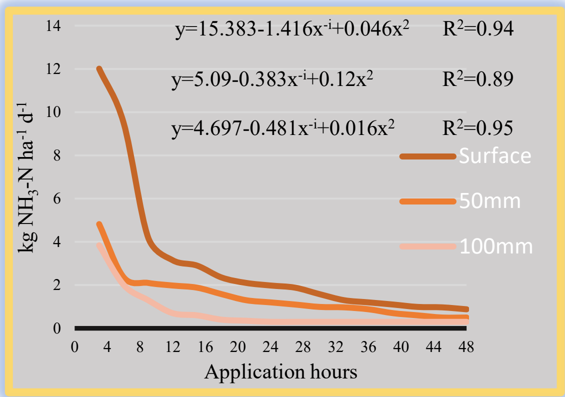


**Fig 9.** Rate of ammonia emission measured.

Surface application using liquid manure resulted in the highest ammonia emission value. It was approximately 70% high in compared to the inject manure 100 mm subsurface. Apparent losses of N were highest at surface application. That was by 60 percent higher than inject manure in 50 mm subsurface and by 70 percent higher than inject manure in 100 mm subsurface (Fig 10).

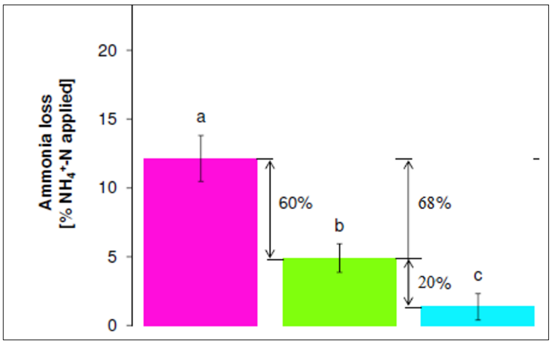


**Fig 10.** Total amount of emitted ammonia from different treatments method during the experiment.

Analysis of variance (ANOVA) was performed with application type as main factors. In table 1, the effect of fertilizer applicator type on ammonia emission was analysed (ANOVA, LSD test).

**Table 1.** The statistical relationship between application method (On surface, Subsurface) and ammonia loss.

| (I) method | (J) method | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| surface | 50mm | 1.53938* | .71406 | .036 | .1012 | 2.9776 |
| | 100mm | 2.26187* | .71406 | .003 | .8237 | 3.7001 |
| 50mm | surface | -1.53938* | .71406 | .036 | -2.9776 | -.1012 |
| | 100mm | .72250 | .71406 | .317 | -.7157 | 2.1607 |
| 100mm | surface | -2.26187* | .71406 | .003 | -3.7001 | -.8237 |
| | 50mm | -.72250 | .71406 | .317 | -2.1607 | .7157 |

*. The mean difference is significant at the 0.05 level.

Was a highly significant correlation coefficient of 0.89 (R2 = 0.95). Emission experiment seems to depend on type of application technique, as shown in table. Surface application using liquid manure resulted in the highest ammonia emission value. There was significantly (P=0.05) different in the ammonia emission, between the surface apply method and injection manure in soil methods. But there was not any significantly different between ammonia emission amount in injection subsurface methods (100 mm and 50 mm deep).

## 4 Construction

Due to the increase in the number of dairy cattle farms and substantial amounts of animal wastes are being produces each year. Therefore, has made it necessary to evaluate the barn manure without creating an environmental problem. Liquid manure in our country generally applied as a surface application, whereas it causes a loss of ammonia nitrogen by evaporation and reaching until 90% and causes significant environmental problems and economic loss. In this study, it was determined that when liquid manure was applied as an injection into soil, there was an average of 70% less nitrogen loss than traditional on surface applied. Manure application management make minimum volatility of the nitrogen into atmosphere so ammonium nitrogen nearby the roots is immediately available or will quick reached by the roots of plants. Studies of crops other than those mentioned in this article will need to evaluate the economic and environmental benefits machines for injection manure in soil a covered that.

## References

1. M. Blanco, *Supply of and access to key nutrients NPK for fertilizers for feeding the world in 2050*, Agronomos Etsiaupm. We Engineer Life Food and Environment, (2011)
2. FAO, Food and agriculture organization of the United Nation, http://www.fao.org
3. Asman WAH, *Ammonia emission in Europe: updated emission and emission variations.* RIVM, Bilthoven, p 88, (1992)
4. Jan Willem Erisman, *how a century of ammonia synthesis changed the world*, Nature Geoscience, DOI: 10.1038/ngeo325, (September 2008)
5. Eurostat, statistics Explained, Agri-environmental indicator- ammonia emissions. ISSN 2443-8219. International Journal of Agronomy 13, (2017)
6. Agurrie-villegas, Horacio A., Rebecca A. Larson, Larry Chase, Michel A, Wattiaux, Sanjeewa D. Ranathunga, and Matthew D. Ruark, *Daily cow nitrogen efficiency. Sustainable Daily Fact Sheet Series,* University of Wisconsin-Extension, (2017)
7. Wang Q., Shi C.J., J. *Research progress of ammonia volatilization in turf ecosystem*, Subtroptical Plant Science. 40 80-84, (2011)
8. J Yang, Y Jiao, W Z Yang, P Gu, S G Bai, L J Liu, 2017, *Review of methods for determination of ammonia volatilization in farmland*, IOP Conf. Series: Earth and Environmental Science 113, 012022doi:10.1088/1755-1315/113/1/012022,(2018)
9. O. T. Denmead, *Micrometeorological methods for measuring gaseous losses of nitrogen in the field*, January 1983 DOI: 10.1007/978-94-017-1662-8_5, https://www.researchgate.net/publication/287456681, (1983)
10. Viney P., Jessica B., Candis S.C, Hugo H.R., *Dynamic Chamber System to Measure Gaseous Compounds Emissions and Atmospheric-Biospheric Interactions.* ResearchGate 10.1007/1-4020-4232-9_7 vol. 9, no. 5, pp. 1611–1632, 2012, (2006)
11. Lockyer, D. R. *A system for the measurement in the field of losses of ammonia through volatilization.* J. Sci. Food Agric. 35(8): 837-848. (1984)
12. Christensen B T; *Sommer S V Volatilization of ammonia from fertilizers and manure. Methodology and loss of ammonia from urea and urea-ammonium-nitrate.* Tid-sskrift Planteavls, 93, 177Ð190, (1989)
13. Thompson, R., Pain, B., and Rees, Y. *Ammonia volatilization from cattle slurry following surface application to grassland*. Plant Soil, 125: 119–128. doi:10.1007/BF00010751. (1990)
14. APHA. *Standard methods for the examination of water and wastewater. 20th ed. American Public Health Assoc*., NW, Washington, DC. (1998)
15. Harper, L. A. Personal communication. 4 October 1996. Watkinsville, Ga. (1996)
16. Balsari P., Airoldi G., Gioelli F., *Maize organic fertilization by means of a modular slurry spreader.* 10th International workshop of the European, (2002)